REQ. NO. 2-9090

Iron Ore Company of Canada

CONTRACT REPORT NO. OSQ82-00140

COM COMBUSTION TEST

AN

I.O.C./EMR COOPERATIVE EVALUATION

Work on this project was conducted under the auspices of
the Canada Centre for Mineral and Energy Technology,
Energy, Mines and Resources, Canada.

DSS File No: 23SQ.23440-2-9090
DSS Contract Serial No: ~~OSQ80-00140~~ OSQ82-00140 (AS PER PROG. OFF.)
CANMET Project No: 430706
CANMET Scientific Authority: Mr. G.N. Banks

64 pp

Management Support Services
Energy Management Group
1982 10 22

EXECUTIVE SUMMARY

I.O.C., in accordance with CANMET/EMR, has undertaken the cooperative evaluation of a combustion field trial of 50/40/10 coal-oil-water mixture fuel in its Ore Dryer at Sept-Iles terminal, as a substitute for Bunker «C» oil.

The slurry, supplied by CoaLiquid Inc., was transported from Shelbyville, Kentucky, to Champlain, New York, where it was transferred to three tank trucks and further transported to Sept-Iles. Stability of the fuel remained unaffected during this long distance haul.

Carried out during July 1982, this test burn demonstrated that COM fuel can be substituted for Bunker «C» oil in existing equipment without major alterations, and that dual-fuel firing can be retained if fuel flexibility is required. A low pressure-velocity Forney-Verloop burner successfully burned diesel oil, No.6 oil and COM.

NOTE: The views and opinions expressed in this report are those of the authors, and not necessarily of EMR and/or I.O.C. management.

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1.0 INTRODUCTION

The iron ore industry, together with the entire economy, is bearing the brunt of the present recession. Plants are being shut down despite the concerted efforts towards improved productivity.

The Energy Management undertakings of the Compagnie minière IOC are good examples of productivity improvements to aid survival. Tests such as this may allow us to reduce the high cost of the energy intensive iron ore products. The company operations rely heavily on petroleum fuels. The railway and mine mobile equipment use distillate fuels, while the beneficiation plants consume residual oil in large capacity industrial burners.

The recent energy conservation measures have proven to be excellent cost-avoidance tools in spite of the rapidly inflating oil (24% per year) prices. However, despite these major savings, energy expenditures have continued to increase. We now realize that to win the war against rising energy expenses, the company will have to switch to the least cost energy sources when and where possible.

I.O.C. representatives have attended meetings of the Coal Liquid Mixtures Working Group formed in the Maritime Provinces. The «raison d'ētre» of the CLM Group is the switching of the electrical utilities from residual oils to coal slurries in conformance with the federal «off-oil» policy.

The present report is the result of the I.O.C./EMR cooperative evaluation of a coal/oil/water slurry burn test. Its purpose is to transfer the state-of-the-art technology from the development stage to the operational units of candidate industries.

The following are excerpts from the «Statement of Work» reproduced from the EMR/DSS request for proposal #23SQ.23440-2-9090:

Requirement:

CANMET/EMR, in their research program on coal liquid mixture technology development, require industrial field trials to be conducted with coal-oil-water mixtures as a substitute for Bunker «C» oil. Through the operations of the CoaLiquid Mixture Working Group in the Maritimes, a combustion test of 50 hours duration has been set up at the Sept-Iles «Terminal Ore Dryer» of the Iron Ore Company of Canada (I.O.C.). in Sept-Iles, Québec.

The technical report supplied by I.O.C. will contain:

a) data on the technical operation of the dryer under normal operating conditions using oil fuel only. These data may encompass flame characteristics ; firing rate; dryer loading characteristics (% H2O feed and output); emission characteristics if relevant; dryer productivity as a function of ore characteristics and fuel consumption;

b) data on the fuel storage, pumping, delivery and combustor systems for the coal-oil-mixture burn tests; nominal analytical data and samples of the coal slurry fuel;

c) data on the combustion characteristics and dryer process characteristics using coal-oil mixture fuel, i.e. the same spectrum of information generated under a);

d) a detailed log of all measurements and observations made on site during the field trial including references to difficulties encountered;

e) Other information deemed relevant by I.O.C. engineers.

2.0 Normal Operation Of The Ore Dryer

The test site was the drying plant located in our Sept-Iles Terminal, used to reduce the moisture content of direct shipping ore produced in Schefferville. This ore consists mainly of hematite, limonite, and goethite and is sized to 90% minus 1¨inch in a crushing/screening facility at the mine site.

The dryer product is blended with other ores to produce the desired moisture content for shipping.

A direct fired air heater equipped with a wide range mechanical burner, operating at high oil pressure, supplies the hot gases to perform the drying of the ore, nominally from 15% to 8% moisture. At full load capacity, the burner heat release is 100 000 000 Btu/h, using Bunker «C» fuel.

The air required to perform this operation is supplied by an air blower at a nominal rate of 43 000 scfm. The air enters the windbox around the periphery of the air heater and is further divided into combustion and secondary air. This flow arrangement is designed to cool down the refractory lining of the air heater and effect a small heat recovery.

The hot air is pulled through the rotary kiln by two exhaust fans operating in parallel. The dust collecting equipment consists of four cyclones and two scrubbers.

Typical operating results for 1981 and 1982 can be summarized as follows:

		1981	1982
Net feed (nat'l)t		747 754	338 090
% Moisture		13.52	14.10
Discharge (nat'l)t		706 271	317 167
% Moisture		8.43	8.51
Water evaporated, t		41 483	20 923
Feed rate t/h		325	311
Water evap. t/h		18.0	19.2
Fuel	Diesel, L	247 370	109 430
	Bunker «C», L	3 839 290	1 853 866
	Waste oil, L	555 521	314 140
	COM, L	-	97 397
Specific heat consumption, (Btu/lb water evap.)		1 988	2 012

During June 1982, to establish reference norms for comparison, performance tests were carried out on the Ore Dryer while firing on No. 6 oil with the original Peabody burner. In addition, this test allowed us to identify several fuel saving opportunities, which will be implemented prior to the next seasonal operation. The complete set of results are included in Exhibit 1.

3.0 COM Supply Circuit

Exhibit 2 shows schematically the COM supply circuit used during this test.

3.1 Storage

The fuel shipped in six tankers from Shelbyville, KY, to Champlain, NY, was transported from Champlain to the plant site in two 9 000 IG and one 5 000 IG tank trailers, successively. The three tank trailers were positioned on the test site, respectively on July 12th, 16th and 21st. These reservoirs were kept at around 140°F by means of steam heating coils.

The fuel was transferred to a 1 000 gallon day tank as required by the operation of the air heater.

3.2 Pumping and Delivery

In the day tank, the slurry was preheated by steam coils. The slurry temperature was boosted up to 250°F in two heat exchangers in series prior to combustion. A progressive cavity Moyno pump powered via a variable speed drive train was used to regulate the quantity of COM burnt.

To protect the supply pump from any problems at the burner end, the circuit included a COM return line, a rupture disc and a pressure relief valve.

At the burner end, we connected the existing Bunker «C» loop to the COM circuit.(Exhibit 2)

The automatic shut-off valve for burner protection was controlled by: (1) Fireye flame safeguard, (2) all normal interlocks and oil pressure and temperature limit switches on the Bunker «C» fuel train of the original burner. These latter limits were maintained as the simplest means of bypassing their interconnection with the flame safeguard while using COM fuel and retaining their availability while firing Bunker «C». It was necessary to circulate diesel oil or Bunker «C» at normal pressure to «make» these contacts.

Diesel and Bunker «C» fuel were originally to be pumped via the Coaliquid trailer mounted equipment. It was found to be simpler to effect changeover to COM fuel at the burner front by bleeding in from the COM system while reducing Bunker «C» to zero in the original fuel train.

3.3 The Burner

For the purpose of the test, instead of modifying the existing Peabody burner, a separate air atomized burner was rented from Forney Engineering Co. of Dallas, Texas.

This Forney-Verloop burner consists of a swirl atomizer head and two counter-rotating air streams for further atomization. Air is supplied to the burner at approximately 35" W.C. pressure and COM pressure at the inlet of the gun was about 140 psig.

A swirl control rod in the burner allows for adjustment of the flame from short and bushy to long and feathery. A diagram of the COM burner is included as Exhibits 3 and 3A.

3.4 The Fuel

The COM is basically a tertiary mixture of coal, oil and water. The COM purchased from Coaliquid Inc. of Kentucky is an emulsion prepared by ultrasound. Coal is first pulverized 80% to 90% minus 200 mesh, and then mechanically blended with the desired amount of oil and water before passing through an ultrasonic device. The slurry once passed through this ultrasonic device becomes an oil/water emulsion with the coal remaining in suspension.

The nominal composition of the Coal/Oil/Water slurry used was 50/40/10 percent by weight. The average calorific value is 166 000 Btu/gal.

Fuel in three deliveries from Shelbyville, Kentucky, was tested as shipped and after delivery to Sept-Iles. The CoaLiquid (CLI) laboratories reported the former and Technical University of Nova Scotia (T.U.N.S.) reported the latter.

SAMPLE	REPORTING AGENCY	% WATER	% SOLIDS	% OIL	BTU/lb.	% ASH
961-COMTk312 July 21, 1982	CLI	9.12	48.96	41.92	15 091	2.67
	T.U.N.S.	9.50	49.10	41.40	14 955*	2.30
962-COMTk115 July 12, 1982	CLI	9.01	50.21	40.78	15 091	2.39
	T.U.N.S.	9.50	48.20	42.30	14 976*	2.50
962-COMTk260 July 16, 1982	CLI	8.40	48.44	43.16	15 351	2.30
	T.U.N.S.	8.90	48.50	42.70	14.827*	2.70

4.0 COM Burn Test in the Ore Dryer

4.1 Objectives of the Test

The objectives of this trial can be established as follows:

- -Show that the slurry remains homogeneous during transportation between Shelbyville, Kentucky, and Sept-Iles, Québec.
- -Demonstrate that COM can be handled like standard heavy fuel oils.
- -Evaluate COM as a substitute of Bunker «C».

*H.H.V. reported by T.U.N.S. was based on calculated values from elemental analysis. Sulphur % had been tentatively set at 3.0% pending completion of analysis. Actual values expected to be less than 1.0% would increase H.H.V. by about 100 Btu/lb. Additional analytical data is shown in Exhibits 4, 5 and 5A.

-Observe the burning characteristics (burner wear and tip plugging).

-Familiarize operators and other groups with this type of fuel.

-Establish the background for future conversions.

4.2 Outline of the Test

Between July 20th and 23rd, 1982, 21 500 IG of a coal-oil-water mixture were burnt in the Sept-Iles Ore Dryer. The COM was fired for 47 hours 45 minutes during the four days, including 34 hours 20 minutes uninterrupted firing near maximum heater temperature. Average fuel rate consumption was 450 IG/h.

The air heater generates roughly 43 000 scfm of hot dry air (1700°F to 2100°F) to evaporate a controlled amount of the moisture from the ore. During the COM firing period, air surveys were carried out to evaluate the performance of the dryer. (See exhibit 6 for sampling arrangement)

The kiln was to be operated under the same conditions as when burning Bunker «C» and the feed rate to the dryer was also to be kept at a normal rate. For dryer feed and discharge moisture, refer to exhibit 7.

4.3 Test Results

Table A, Exhibit 1A , shows the test results. The COM fuel rates were determined by outage measurements in the fuel tank-trucks. A series of iterations using the fuel rate, and the feed and product moistures, allowed us to improve the measurement inaccuracies.

Table B (Exhibit 1A), shows the test results after such iterations taking into account:

a) The 0.06 dryer product carbon content (Exhibit 8).

b) The fuel rate derived from the total heat gain of the air heater gas flow, corrected for carbon losses.

c) System unaccounted losses set at 5.0% of fuel energy.

d) Dryer product moisture adjusted to meet the above restraints.

Comparing Table B for fuel #6 with Table B for COM, it is seen that the performance data from the two tests are similar. The kiln performance as an ore dryer was not affected by the change in fuel from heavy oil to coal-oil-water mixture.

Table C (Exhibit 1A), shows the results of July 21st test (No.6) when evaluating possible energy savings associated with reduced air infiltration. Forced draft air was set at maximum and infiltration reduced to 35%.

4.3.1 Burning COM

The Forney burner successfully fired No.2, No.6 and COM fuels with essentially equal ability. No provision is incorporated in our kiln heater to observe the flame longitudinally, making it difficult to determine flame intensity and shape. The swirl control of the Forney burner allows adjustment of the flame from short and bushy to long and feathery. During No.6 firing, it was noted that fireflies impinged on the heater wall. Lengthening the flame corrected this; however, the Forney combustion engineer felt that higher No. 6 oil temperature, closer to 210°F, would improve atomization and give better performance. No. 6 Oil temperature was 185°F, whereas COM temperature was 230°F.

While firing COM, it was noted that a high volume of fireflies were impinging the heater wall and that fireflies brightened the entry to the kiln. Attempts to lengthen the flame to correct for side wall impingement further increased the brightness of the discharge area into the kiln, indicating that the flame shape could be modified. It should be noted here that the Forney burner tip was approximately 12 inches further into the throat of the air heater than the original position of the Peabody burner. This position was determined by improper measurements taken from drawings and telephone to the burner supplier. It was not feasible to alter this during the short test duration.

An early dismantling of the temporary COM fuel handling train forced us to shut down on No. 6 oil on the last day. This caused a coke deposit to be formed on the heater walls, disguising any COM related residues. No deposit of ash was noted on the heater floor after the tests.

Thermograms taken using a thermovision camera supplied by AGAtronics showed two hot spots along the heater shell, confirming that the oil burns off first, and then the coal particles. This results in two distinct areas of high heat release. The long residence time required for the coal particles to burn out explains the second peak of flame intensity. The combustion engineer suggests that the combustion and process air be better split so that flame quenching is minimized. Low excess air firing followed by mixing in the burner exit with the balance of the forced air could improve combustion efficiency.

Analysis of product for unburned carbon showed approximately 0.05% by weight in the dry kiln product for No.6 oil firing before the COM tests (Peabody burner) and 0.06% by weight while firing COM. Additional analyses (Exhibit 8) of daily averages during the test periods in June and July showed the range of %C in dry product to be 0.03 to 0.07%, on COM and 0.03 to 0.05 on No.6 oil.

In conclusion, the heat release profile, as theoretically expected, was noted to be two-stage, flatter and longer than the No. 6 oil profile. This difference, in this application did not prevent the generation of the required amount of hot dry gases for ore drying.

While firing COM, there was no difficulty experienced in maintaining heater temperature near the maximum (1220°C high trip) with normal 0.2" W.C. negative draft.

COM fuel was shown to be an acceptable substitute for No. 6 oil in the Ore Dryer. It was used in a dual fuel mode in the test burner with acceptable control; however, provisions would have to made to prevent cross contamination of the two fuels, in a permanent installation.

4.3.2 Burner Considerations

The burner oil tip used during the test had been employed in an earlier test burn at New England Public Service Co. (NEPSCO). The 316 stainless steel tips such as this one had shown high erosion rates with 35% coal fuel and were replaced by tips having nitrided surfaces or other hardened materials. These had shown acceptable wear rates.

In choosing a burner tip for our tests, Forney had considered wear immaterial for the short duration and suggested the use of a used 316 stainless still tip that «looked O.K.». A spare brand new tip was also delivered and available at the site in case of need. When measured after our tests, the previously used tip was 0.011" oversize from the 0.3125" (5/16") aperture measured on the new tip.

A recent study by Centre for Energy Studies from the Technical University of Nova Scotia points out that the externally atomized burners (such as the Forney burner used here) operating at low (less than 150 psig) fuel pressure are best suited for firing COM fuels. The Forney Verloop burner with hardened nozzles has been listed with Vortometric burners as among the short list of recommended equipment.

The very simple 3/4" diameter fuel delivery pipe with 1/4 turn swirl in the nozzle before leaving the 5/16" diameter single orifice results in minimal restriction to flow of COM fuel. No clogging of the burner tip was noted after 48 hours of operation on COM and a further 48 hours on No.6 oil.

4.3.3 Emissions

When planning the COM Burn Test at the Dryer, it was intended to monitor the possible changes for environmental control. The lack of isokinetic sampling conditions and the high cost to modify the dryer stack to create this state did not permit a meaningful sampling of the scrubber exhaust gases.

The stack discharge was visually monitored to observe the quality of the plume. Except for those periods of time when the combustion was upset due to power failures or other reasons (switching fuels, start-up, etc.), the stack discharge color was not different than when firing Bunker «C» oil. A thermograph picture of the stacks taken on July 22 by Agatronics is shown in Exhibit 9. Normally, water vapor will not show isotherms in a thermogram. The isotherms in the left stack can only be explained as dust contained in the vapor. The right hand side plume consists only of water vapor.

A look at the exhaust fans power consumption and shaft speed also indicates that the two fans are operating differently. Fan No.2 has more installed power than the south side fan and is also running faster.

	NORTH FAN #2	SOUTH FAN #1
Power, HP	240	210
Speed, RPM	837	798

This condition represents a difference in the operating mode of the two scrubbers and cannot be attributed to the type of fuel being used. The high dust loading of one plume is thus clearly the result of this imbalance which overloads one scrubber beyond its collection design-capacity.

Analyses of the carbon content in the scrubber discharge, the cyclone underflow and the dryer discharge showed the following results:

	%
Cyclone U/F	0.27
Scrubber disch.	0.28
Dryer Prod. (COM)	0.06
Dryer Prod.(F.O. #6)	0.06

Since we do not know the carbon content of the stack exhaust, we cannot show the overall C distribution, but we established that the carbon content of the dryer product was 0.05 when burning No.6 fuel, by analysis of existing samples of dry product.

The analysis above is based on single samples taken for a spot check on carbon carryover. The burner was known to require considerable adjustment for longer term firing. No attempt was made to optimize burner performance during the test burn.

The COM test at the dryer did not quantify the NOx, SOx, unburnt hydrocarbons, or particulates in the dryer plume.

The monitoring of the change in such pollutant concentrations would be included in long term demonstrations. Such information will allow us to determine the requirements (if any) of upgrading the existing pollution control equipment.

Particulate emission changes were monitored in a lime-kiln burn-test at St.Regis in Jacksonville, Florida, and results are shown in Exhibit 9A.

4.3.4 Socio-Technical Considerations

The successful completion of the test proves that the concept of COM burning is a feasible proposition. Involvement of several groups from IOC in the test was a good way to distribute the information on the differences of burning Coal-Oil-Water mixtures as opposed to Bunker 'C' or diesel fuel. The groups involved in this test were: Energy Management; Technical Services; Traffic; Contracts; Terminal Operations; Carol Process Engineering; Coaliquid Inc.; Energy Mines and Resources and NRC personnel from the federal government. It was the opinion of all involved that the technical and operational gains were significant. The high degree of cooperation between the operators and the technical people involved was a mutually educational experience.

We believe that the frequent visits of higher management during the test period reinforced the idea that the Coal-Oil Mixture burning can be one of the important alternate process fuels in IOC for the future.

4.4 Detailed Chronology of the Test

On July 19, 1982, we finished installing the atomizing air fan as well as fuel supply lines and burner at the end of a scheduled shut down. Typical test data sheets are shown in Exhibit 12.

July 19th

-22:30	Finished equipment installation
-22:30 to 24:00	Trying to light up the air heater. Main difficulty being the relative distance of burner tip and ignitor.

July 20th	
00:00 - 00:40	Trying to light up the air heater
00:40	Started heating up the air heater
08:00 - 10:30	Switched to Bunker «C» and repaired heat exchanger on COM trailer
11:50 - 12:00	Lost the flame due to drastic change in COM's temperature and pressure
13:50 - 15:00	Dryer down due to power failure
16:00 - 16:05	Dryer down due to power failure
16:20 - 18:15	Stopped burning COM due to problems with one heat exchanger in COM trailer: Burner back to Bunker «C».
18:25 -	Finished heating up period and started feeding the kiln
July 21st	
10:15	Started firing COM
11:00 - 11:15	Lost flame due to power failure
11:50 - 12:00	Lost flame due to power failure
15:20 - 15:40	Lost flame due to power failure
20:00	Stopped burning COM
July 22nd	
09:20	Started firing COM
July 23rd	
19:40	Stopped firing COM - end of test

Total COM burning time: 47 hours 45 minutes.

No major obstacles were encountered through the COM burn test. The following is the list of minor difficulties encountered:

i) Ignitor flame not reaching the new burner tip.
Solution: A hand torch was required only when firing cold.

ii) Automatic shut-off valve, shocking the COM delivery system, rupturing heat exchanger gaskets.
Solution: COM return valve, controlled manually, had to be opened within seconds after a flame-out. Back-up protection was provided by a rupture disc and an adjustable relief valve near the pump.

iii) Discharge fan tripped - lost flame.
Solution: Restart flame (one time) after replacing rupture disc.

iv) Power outages - lost flame.
Solution: Restart flame (three times) after replacing rupture discs.

v) COM delivery systems dismantled too early - not possible to fire No.2 oil at shut down due to lack of controlled bleeding of No.2 from the high pressure system.
Solution: Shut down on No.6 causing coking on heater refractory.

vi) Backfiring induced kiln vibration due to excessive amount of forced draft fan air (49 000 scfm).
Solution: Maintain required negative furnace draft (0.2" WG) by reducing forced air to 30 000 scfm.

5.0 Conclusions & Recommendations

Based on our experience of the COM firing test at the dryer and our past involvements with several slurry manufacturers and users, here is a list of recommended work:

1) A full year demonstration on one of our Carol production lines to study long term effects of COW burning.

2) Follow-up alternate technologies of COW slurry preparation especially with respect to slurry coal content.

3) Stability of fuel when exposed to extreme cold weather cycles.

4) Keep up with burner technology breakthroughs and assess IOC burner conversion possibilities.

5) State-of-the-art revision of slurry metering and fuel train automation.

6) Keep in touch with the federally sponsored developments on Coal-Water-Slurry (CWS) burning in the Maritimes.

Exhibit 10 shows the expected price trends of energy derived from Bunker 'C', coal, and COM slurries. The COM energy price trend as indicated in Exhibit 10 includes $16.80 per short ton of COM for slurry preparation. The difference in fuel price between Bunker 'C' and COM is shown to be 0.68¢ per million BTU by 1984 and $1.08 by 1985. If as a result of market conditions, Bunker «C» price arrives at this level, an investment of the order-of-magnitude required might theoretically be jutified. Whether the company can afford to proceed with such an investment under the conditions shown, will depend greatly upon a very significant increase in business volume and a dramatic increase of the availability of capital.

While neither of these are likely in the near future, the project does show promise and once the capital requirement of fuel processing can be overcome, the capital required for other system modifications should be capable of justification. Since the future costs of oil (NEP influenced) and coal (Exhibit 10) indicate that significant savings are possible, it is recommended that further testing as mentioned herein be continued.

6.0 COM Burn Demonstration At Carol - Proposal

6.1 Abstract

Due to the importance of the Coal/Oil Mixtures (COM) as an eventual alternate fuel for I.O.C. in the future and based on our experience firing COM at the ore dryer, the conceptual design and the budget cost for a one-year COM demonstration at the Carol facilities of I.O.C. are outlined.

The most representative areas for such a test have been selected as being one grinding mill and one indurating machine at Carol.

This long term study will permit us to assess

(1) the effects of COM firing on concentrate and pellets metallurgy,

(2) the quality of pellets produced by the change in heat release of this fuel, (3) and change in dust loading and pollution control equipment.

The capital expenditure involved is estimated at $5.6 million (in 1982 dollars) and include terminal handling facilities for coal, COM preparation unit, and plant modifications including burner adaptations, and all other auxiliaries for COM firing.

6.2 Introduction

The conclusions of the COM firing test at the ore dryer in Sept-Iles have proved that the concept of COM burning has been successfully developed. The next step, prior to a full conversion, is a plant-scale pilot demonstration that would include one small grinding mill and one induration machine as final application points.

Our experience, after the Sept-Iles dryer burn test, is that COM can be handled and fired as easily as heavy oil, at least during summer months.

The purpose of this proposal is to describe the flowsheet (Exhibit 11) as well as the budget cost of this COM burn demonstration. The following criteria have been applied for planning the different aspects of this test.

6.3 Design Criteria

The 1979 plant production rates have been used to estimate COM requirements.

Bunker «C» Consumption

-Small mill	48 000	bbl/year
-Indurating machine	214 000	bbl/year
TOTAL	262 000	bbl/year

Equivalent COM consumption

-Small mill	52 000	bbl/year
-Indurating machine	232 000	bbl/year
TOTAL	284 000	bbl/year
or	884	bbl/day

A modular COM preparation plant offered by CoaLiquid Inc. and rated at 3 600 barrels per day can produce the required amount of fuel in one shift, five-day-per-week operation.

-The coal required to supply the plant will arrive in Sept-Iles in one shipment by a self-unloading boat.

-A new building will enclose the COM preparation plant that will be located in Sept-Iles.

-The slurry will be transported in heater-equipped tank cars from Sept-Iles to Carol.

-Fixed storage tanks with a reserve for three days operation to be intalled close to both the grinding and induration sections.

6.4 Conceptual Design

6.4.1 Sept-Iles Facilities

Reclaim hopper
Reclaim conveyor
Cracker
Electrical package boiler
COM building
COM preparation plant
Tank car loading station

6.4.2 Carol Induration

COM unloading station
Storage tank
Pumping and preheat system
Burning modifications and fuel train

6.4.3 Carol Grinding

Unloading facilities
Storage tank
Pumping and preheat system
Burner modifications and fuel train

6.5. Order-Of-Magnitude Estimate

Based on the previous criteria, the cost of the project is estimated as $5 600 000 in Canadian funds, 1982 dollars, with an accuracy of ± 30%. (Exhibit 11A)

6.6 Short term Burn Test at Carol

It is understood the $\$5.6 \times 10^6$ referred to in the previous section will not be available in the foreseable future. In the meantime, it is recommended to convert only few of the 34 burners of an induration machine and carry out a burn test by trucking the required fuel.

Such an undertaking will not require any fixed investment and the order-of-magnitude estimate is $1 100 000. This estimate is subject to recalculation and refinement before final approval. Burner specifications, fuel requirement and the summary of the cost estimate are shown in Exhibits 13(A) and 13(B).

7.0 EXHIBITS

ZV Ore Dryer Energy Performance	1
ZV Ore Dryer COM Test	1A
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Forney-Verloop Burner	3 & 3A
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ZV ORE DRYER

ENERGY PERFORMANCE

TABLE A

EXHIBIT 1

DATE	TEST	DRIER FEED & DISH (t/h)				WATER EVAP (lb/h)	FUEL CONSUMP (IG/h)	SPEC.FUEL CONS. BTU/lb Water Ev.	EFF. %	AIR FLOWS (SCFM)			TEMPERATURES OF			UNACCOUNTED LOSSES (Btu/h)	HUMIDITY RATIOS			
		FEED	% MOIST	DISCH	% MOIST.					FORCED DRAFT	EXHAUST	INFILTRATION	AIR HEATER BEFORE INFILTRATION	AIR HEATER AFTER INFILTRATION	KILN OFF-GAS		INTAKE AIR	AIR HEATER	AFTER INF.	KILN OFF-GAS
82-06-15	1	359	13.7	336	7.9	49851	452	1630	68.8	34,920	67,000	32,080	1958	1071	147	1,860,532	0.0072	0.0378	0.0231	0.1836
	2	359	13.7	336	7.9	49851	482	1630	68.8	31,100	68,100	37,000	1999	970	148	1,626,014	0.0072	0.0415	0.0229	0.1808
	3	359	13.7	336	7.9	49851	517	1864	60.2	33,450	71,950	38,500	1989	983	150	12,030,501	0.0072	0.0437	0.0242	0.1734
	4	359	13.7	336	7.9	49851	507	1828	61.4	27,750	70,800	43,050	1994	848	151	10,359,109	0.0072	0.0503	0.0241	0.1758
82-06-17	2	334	14.3	312	8.2	48938	483	1774	63.2	36,500	74,300	38,400	2165	1113	160	8,134,941	0.0076	0.0388	0.0228	0.1636
	3	334	14.3	312	8.2	48938	451	1656	67.8	31,680	73,500	41,820	2030	936	161	2,776,347	0.0076	0.0412	0.0220	0.1657
	4	334	14.3	312	8.2	48938	483	1774	63.2	32,070	78,000	45,930	2192	967	162	7,568,684	0.0076	0.0432	0.0222	0.1574
	5	382	14.3	357	8.2	55970	437	1403	80.0	29,960	88,280	58,320	2174	804	162	-10,892,878	0.0076	0.0420	0.0193	0.1562
	6	382	14.3	357	8.2	55970	437	1403	80.0	30,680	87,870	57,190	2192	831	154	- 9,841,628	0.0076	0.0412	0.0193	0.1569
	7	382	14.3	357	8.2	55970	471	1512	74.2	30,810	87,300	56,490	2201	844	152	- 3,762,906	0.0076	0.0437	0.0203	0.1587
	8	382	14.3	357	8.2	55970	445	1429	78.5	30,150	89,400	59,250	2219	815	152	- 6,400,090	0.0076	0.0424	0.0194	0.1546
82-06-18	1	331	14.1	299	4.8	71299	629	1586	70.7	31,460	85,100	53,640	2138	864	154	9,689,480	0.0066	0.0538	0.0240	0.2048
	2	331	14.1	299	4.8	71299	396	998	(+)00.0	32,390	81,750	49,160	2188	930	158	29,944,078	0.0066	0.0353	0.0180	0.2069
	3	331	14.1	299	4.8	71299	581	1465	76.6	35,580	81,390	46,310	2210	1926	150	7,418,100	0.0066	0.0451	0.0233	0.2113

TABLE B

EXHIBIT I

DATE	TEST	DRYER FEED & DISH (t/h)				WATER EVAP. (lb/h)	FUEL CONSUMP (IG/h)	SPEC. FUEL CONS. BTU/lb Water Ev.	EFF. %	AIR FLOWS (SCFM)			TEMPERATURES OF			UNACCOUNTED LOSSES (Btu/h)	HUMIDITY RATIOS			
		FEED	% MOIST	DISCH.	% MOIST					FORCED DRAFT	EXHAUST	INFILTRATION	AIR HEATER BEFORE INFILTRATION	AIR HEATER AFTER INFILTRATION	KILN OFF-GAS		INTAKE AIR	AIR HEATER	AFTER INF.	KILN OFF-GAS
82-06-15	1	359	13.7	336	8.5	44,987	467	1866	60.1	34,920	67,300	32,080	1958	1071	147	4,392,600	.0072	0.0388	0.0237	0.1683
	2	359	13.7	336	9.3	38,402	429	2008	55.9	31,100	68,100	37,000	1999	968	148	4,218,795	.0072	0.0398	0.0221	0.1434
	3	359	13.7	336	8.8	42,531	456	1927	58.2	33,450	71,950	38,500	1989	979	150	4,106,263	.0072	0.0394	0.0222	0.1494
	4	359	13.7	336	10.1	31,699	387	2194	51.1	27,750	70,800	43,050	1994	840	151	3,143,955	.0072	0.0401	0.0201	0.1163
82-06-17	2	334	14.3	312	7.3	55,613	530	1713	65.5	36,500	74,900	38,400	2165	1116	160	5,048,696	.0076	0.0419	0.0743	0.1844
	3	334	14.3	312	9.2	41,366	438	1903	59.0	31,680	73,500	41,820	2030	935	161	3,647,286	.0076	0.0402	0.0217	0.1429
	4	334	14.3	312	8.5	46,683	476	1833	61.2	32,070	78,300	45,930	2192	966	152	4,174,815	.0076	0.0426	0.0220	0.1509
	5	382	14.3	357	10.2	38,457	450	2103	53.4	29,960	88,280	58,320	2174	805	152	3,631,062	.0076	0.0431	0.0196	0.1133
	6	382	14.3	357	9.8	42,022	467	1997	56.2	30,680	87,870	57,190	2192	833	134	3,972,588	.0076	0.0435	0.0201	0.1231
	7	382	14.3	357	9.8	42,022	467	1997	56.2	30,810	87,300	56,490	2201	844	152	4,272,631	.0076	0.0434	0.0202	0.1238
	8	382	14.3	357	9.9	41,134	461	2014	55.7	30,150	89,400	59,250	2219	816	152	3,906,246	.0076	0.0437	0.0198	0.1188
82-06-18	1	331	14.1	299	8.7	43,168	457	1903	59.0	31,460	85,100	53,640	2138	853	154	3,960,304	.0066	0.0409	0.0193	0.1285
	2	331	14.1	299	8.2	46,908	483	1851	60.6	32,590	81,750	49,160	2188	936	158	4,589,309	.0066	0.0416	0.0205	0.1441
	3	331	14.1	299	7.1	54,994	528	1726	65.0	35,580	81,390	46,310	2210	1023	150	5,127,967	.0066	0.0416	0.0218	0.1646

TABLE A

ENERGY PERFORMANCE

WITH COH FUEL

EXHIBIT 1A

DATE	TEST	DRYER FEED & DISH (t/h)				WATER EVAP (lb/h)	FUEL CONSUMP. (IG/h)	SPEC. FUEL CONS. BTU/lb Water Ev.	EFF. %	AIR FLOWS (SCFM)			TEMPERATURES OF			UNACCOUNTED LOSSES (BTU/h)	HUMIDITY RATIOS			
		FEED	% MOIST	DISCH.	% MOIST.					FORCED DRAFT	EXHAUST	INFILTRATION	AIR HEATER BEFORE INFILTRATION	AIR HEATER AFTER	KILN OFF-GAS		INTAKE AIR	AIR HEATER	AFTER INF.	KILN OFF-GAS
82-07-20																				
	1	210	14.0	202	10.5	19,091	224	2054.3	54.6	33,176	75,800	42,624	2111	980	174	2,402,102	.01007	0.0232	0.0158	0.0677
	2	213	13.9	202	9.2	24,265	278	1900.8	59.0	49,255	75,600	26,345	2007	1343	160	3,196,703	.01007	0.0211	0.0172	0.0870
82-07-21																				
	1	240	14.3	230	10.5	22,441	261	1929.7	58.1	29,233	80,100	50,876	2104	832	167	2,805,954	.0097	0.0271	0.0161	0.0769
	2	330	13.3	317	9.8	28,201	316	1859.1	60.4	29,533	79,400	49,867	2086	840	144	3,188,334	.0110	0.0319	0.0188	0.0960
	3	341	14.2	326	10.3	32,692	319	1619.0	69.3	28,070	77,470	49,400	2106	828	160	- 3,388,229	.0110	0.0332	0.0190	0.1108
	4	341	14.2	326	10.3	32,692	319	1619.0	69.3	28,074	75,930	47,856	2104	844	159	- 2,828,532	.0110	0.0332	0.0192	0.1128
	5	256	15.7	242	10.8	31,008	297	1589.1	70.6	28,399	71,660	43,261	2068	882	160	- 1,079,653	.0110	0.0314	0.0191	0.1132
	6	265	14.7	249	9.0	36,642	297	1344.8	83.4	28,044	74,200	46,156	2005	819	164	- 8,364,774	.0110	0.0317	0.0188	0.1262
82-07-22																				
	1	267	14.5	254	10.2	28,181	316	1860.5	60.3	25,328	73,770	48,442	1992	747	161	3,442,864	.0113	0.0356	0.0197	0.1027
	2	263	15.0	248	9.9	32,825	348	1758.9	63.8	27,370	73,880	46,510	2079	833	159	3,740,963	.0113	0.0361	0.0205	0.1171
	3	263	15.0	248	9.9	32,825	361	1824.7	61.5	25,976	73,140	47,164	2111	815	177	4,096,398	.0113	0.0384	0.0209	0.1185
	4	261	14.6	247	10.0	29,358	318	1797.1	62.4	28,374	77,910	49,546	2169	851	145	3,261,511	.0097	0.0316	0.0177	0.0996
	5	267	14.7	250	9.0	36,808	435	1960.8	57.2	26,811	74,260	47,449	2170	855	145	15,016,645	.0097	0.0414	0.0211	0.1289
	6	267	14.7	250	9.0	36,808	435	1960.8	57.2	29,090	77,080	47,990	2145	878	141	15,190,547	.0097	0.0389	0.0207	0.1245
	7	262	14.7	245	9.0	36,200	428	1961.6	57.2	31,084	78,100	47,016	2187	937	141	15,287,614	.0097	0.0366	0.0204	0.1212
82-07-23																				
	1	252	16.0	232	8.6	45,059	400	1472.9	76.2	31,401	73,850	42,449	2136	974	149	1,810,809	.00786	0.0327	0.0184	0.1512

TABLE B

EXHIBIT 1A

DATE	TEST	DRYER FEED & DISH (t/h)				WATER EVAP (lb/h)	FUEL CONSUM (IG/h)	SPEC.FUEL CONS. BTU/lb Water Ev.	EFF. %	AIR FLOWS (SCFH)			TEMPERATURES OF			UNACCOUNTED LOSSES (BTU/h)	HUMIDITY RATIOS			
		FEED	% MOIST	DISCH	% MOIST.					FORCED DRAFT	EXHAUST	INFILTRATION	AIR HEATER BEFORE INFILTRATION	AIR HEATER AFTER	KILN OFF-GAS		INTAKE AIR	AIR HEATER	AFTER INF	KILN OFF-GAS
82-07-20	1	210	14.0	202	2.5	54,564	489	1487	75.5	33,176	75,600	42,624	2111	994	174	3,882,737	0.01007	0.0388	0.0227	.17924
	2A	213	13.9	202	0.0	65,161	670	1726	65.0	49,255	75,600	26,345	2007	1355	180	21,373,637	0.01007	0.0369	0.0276	.21501
	2B	213	13.9	202	3.7	49,653	466	1557	72.1	33,176	75,600	42,424	2007	947	180	3,739,453	0.01007	0.0375	0.0221	.16495
82-07-21	1	240	14.3	230	6.3	45,126	436	1603	70.0	29,233	80,100	50,867	2104	842	167	3,733,501	.0097	0.0388	0.0203	.14285
	2	330	13.3	317	7.8	43,354	449	1718	65.3	29,533	79,400	49,867	2086	847	144	3,792,840	.0110	0.0407	0.0220	.14078
	3	341	14.2	326	9.6	38,261	434	1862	59.6	28,070	77,470	49,400	2106	835	160	3,660,883	.0110	0.0412	0.0219	.12932
	4	341	14.2	326	9.5	39,049	434	1844	60.9	28,074	75,930	47,856	2104	850	159	3,449,215	.0110	0.0412	0.0222	.13398
	5	256	15.7	242	9.0	41,561	420	1677	66.9	28,399	71,660	43,261	2068	889	160	3,702,570	.0110	0.0399	0.0224	.14857
	6	265	14.7	249	8.8	37,845	405	1776	63.2	28,044	74,250	46,206	2005	825	164	3,146,007	.0110	0.0392	0.0217	.13248
82-07-22	1	267	14,5	254	9.5	32,515	368	1878	59.7	25,328	73,770	48,442	1992	750	161	3,009,654	.0113	0.0397	0.0210	.11687
	2	263	15.0	248	8.9	38,831	410	1752	64.0	27,370	73,880	46,510	2079	837	159	3,309,905	.0113	0.0405	0.0221	.13643
	3	263	15.0	248	9.5	35,243	397	1869	60.0	25,976	73,140	47,164	2111	817	177	3,136,439	.0113	0.0411	0.0219	.12667
	4	261	14.6	247	7.5	44,089	441	1660	67.6	28,374	77,910	49,536	2169	859	145	3,848,259	.0097	0.0400	0.0207	.14382
	5	267	14.7	250	8.2	41,608	419	1671	67.1	26,811	74,360	47,449	2170	854	145	3,515,166	.0097	0.0402	0.0207	.14256
	6	267	14.7	250	7.4	46,325	447	1601	70.1	29,090	77,080	47,990	2145	879	141	3,445,929	.0097	0.0397	0.0211	.15173
	7	262	14.7	246	6.2	52,371	484	1533	73.2	31,084	78,100	47,016	2187	940	141	3,887,364	.0097	0.0400	0.0218	.16765
82-07-23	1	252	16.0	232	7.6	50,595	475	1558	72.0	31,401	73,850	42,449	2136	978	149	4,171,948	.00786	0.0373	0.0204	.16942

TABLE C

EXHIBIT 1A

DATE	TEST	DRYER FEED & DISH (t/h)				WATER EVAP (lb/h)	FUEL CONSUM (IG/h)	SPEC.FUEL CONS. BTU/lb Water Ev.	EFF. %	AIR FLOWS (SCFH)			TEMPERATURES OF			UNACCOUNTED LOSSES (BTU/h)	HUMIDITY RATIOS			
		FEED	% MOIST	DISCH	% MOIST.					FORCED DRAFT	EXHAUST	INFILTRATION	AIR HEATER BEFORE INFILTRATION	AIR HEATER AFTER	KILN OFF-GAS		INTAKE AIR	AIR HEATER	AFTER INF	KILN OFF-GAS
82-07-21	6	265	14.7	249	9.0	36,642	360	1630.1	68.6	43,000	60,000	17,000	1295	956	164	2,995,400	0.0110	0.02374	.02271	.15593
	6	265	14.7	249	9.0	36,642	388	1756.9	63.5	43,000	60,000	17,000	1275	942	164	3,165,075	.0110	.02861	.02362	.15642
	6	307	14.7	270	8.5	59,316	550	1537.9	73.0	43,000	60,000	17,000	1940	1427	164	4,567,546	.0110	.03595	.02888	.24391

COM SUPPLY CIRCUIT

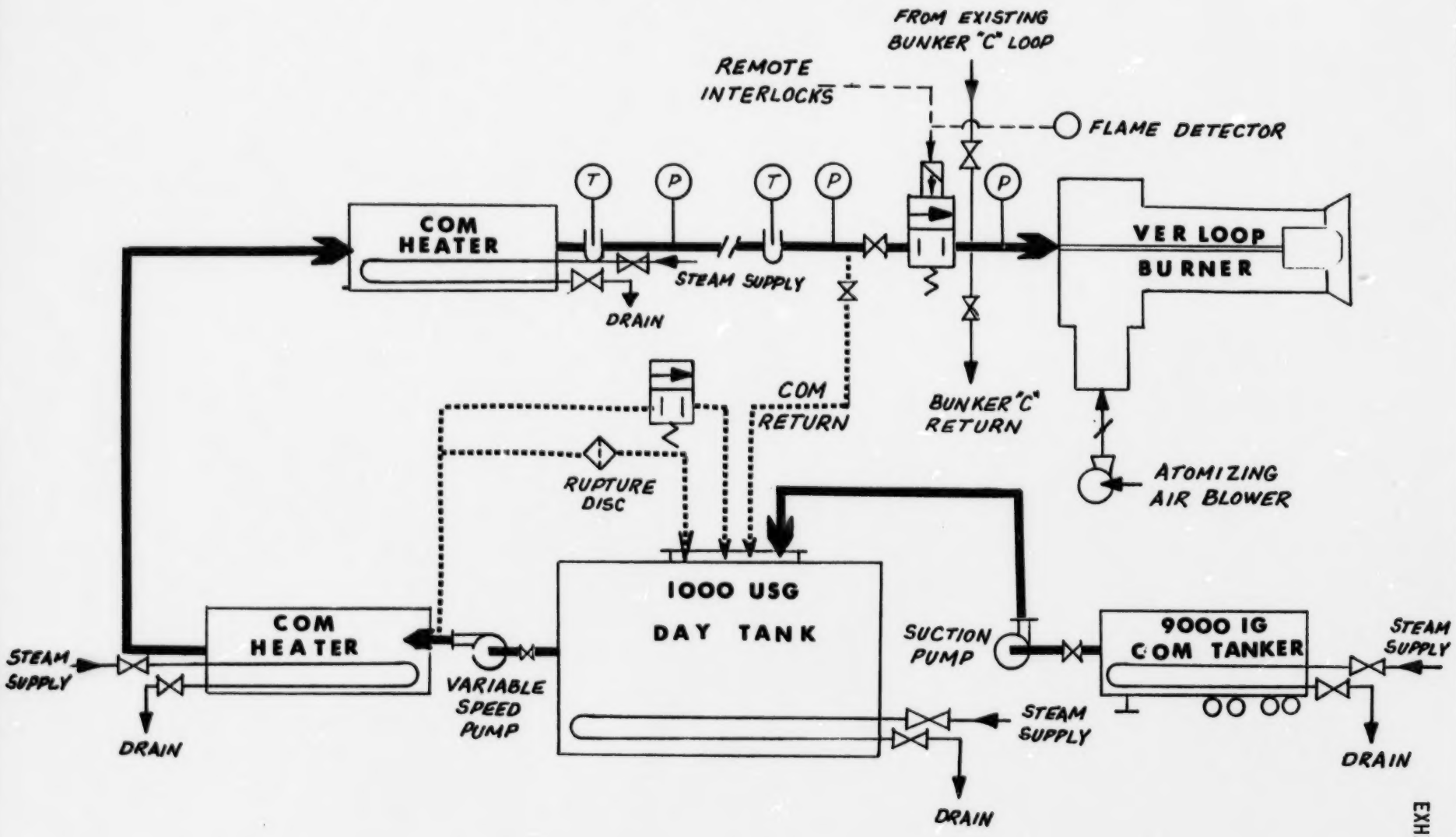
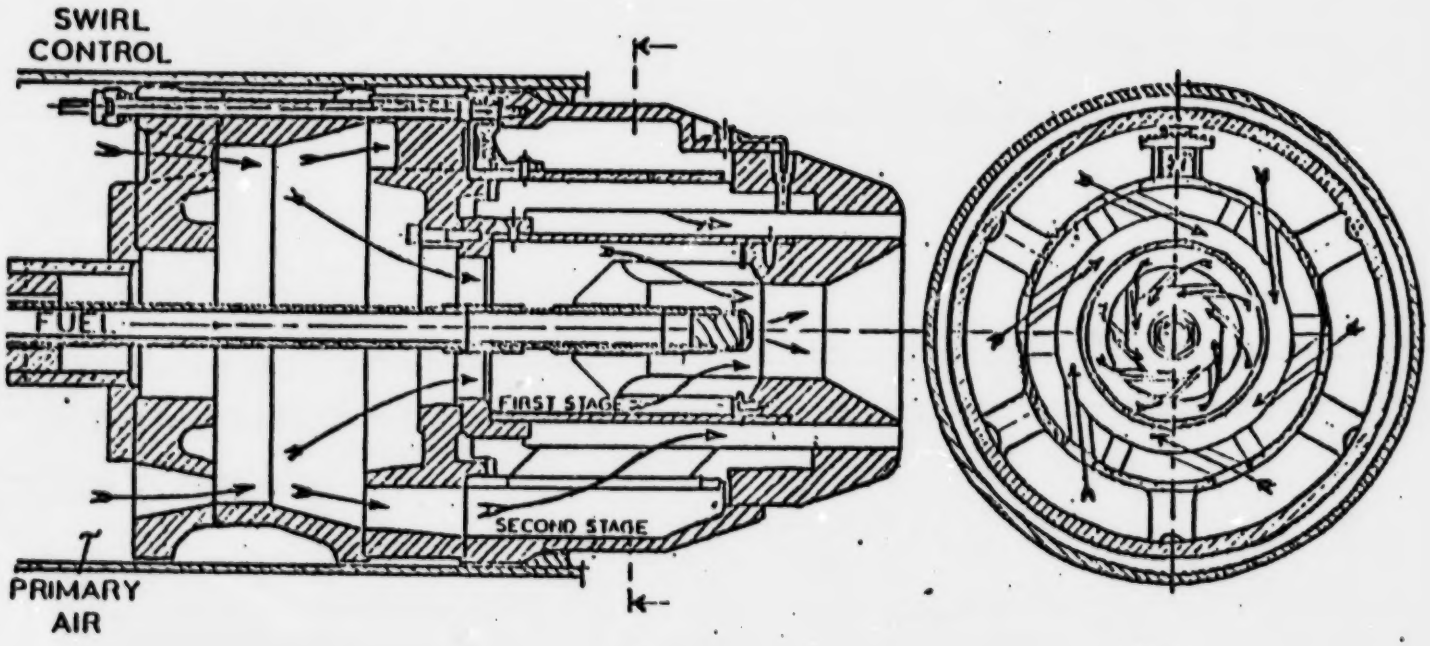


EXHIBIT 2



FORNEY-VERLOOP BURNER

EXHIBIT 3

SKETCH OF THE VERLOOP BURNER

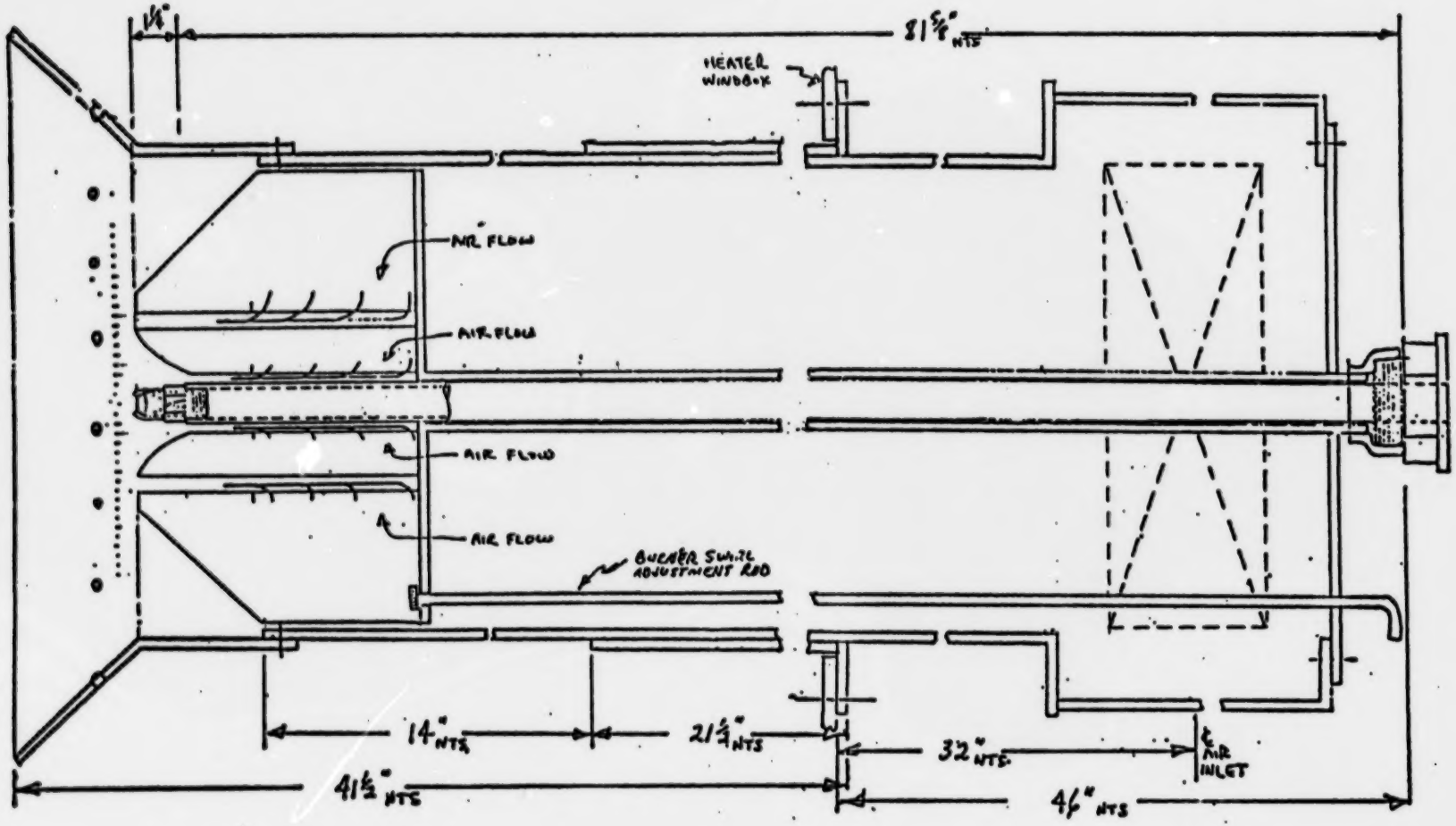


EXHIBIT 3A

EXHIBIT 4

SEPT-ILES ORE DRYER

COM BURN TEST PROJECT

FUEL ANALYSIS

Fuel analysis as tested by CoaLiquid before shipment from Shelbyville, Kentucky

Coal, % Weight	50.32	50.09	50.00	45.45	49.86	48.96
Oil, % Weight	41.66	39.90	41.20	47.27	41.00	41.92
Water, % Weight	8.02	10.01	8.80	7.28	9.14	9.12
Sulfur, % Weight	0.70	0.70	0.78	0.80	0.78	0.78
Ash, % Weight	2.39	2.39	2.39	2.12	2.39	2.67
Sp. Grav.	1.09	1.09	1.09	1.08	1.09	1.08
lb/IG	11.0	11.0	10.9	10.8	10.9	11.0
Flash point °F	304	304	292	292	292	292
Viscosity @ 122°F,cps	11,660	11,660	-	-	-	10,000
Btu/lb	15,091	15,091	15,091	15,870	15,091	15,091
Shipment, lbs.	47,960	40,808	41,087	9,200	49,137	49,128
COM Tanker #	115			260		312

EXHIBIT 5

FUEL ANALYSIS SHEETS

BY CLI

EXHIBIT 5

737 Executive Park, Louisville, Kentucky 40207
(502) 893-0106

COALIQUID. INC.

FUEL ANALYSIS SHEET

SAMPLE # 82021805

DATE JUL. 6 1982

CUSTOMER Iron Ore Canada

COAL USED ( )

Seam: Horse Creek
Source: G+G Coal
BTU/Lb.: 13,951
Ash (%): 3.80
Sulfur (%): 0.78
Moisture (%): 3.99
Hardness: 47
Fusion(Ash): 2450 F+
Volatiles (%): 40.17
Fixed Carbon (%): 52.09
Percent Passing 200 Mesh: 92.9

OIL USED

Type: Fuel Oil #6
Source: Allied Oil
BTU/Lb.: 18,790
Ash (%): 0.28
Sulfur (%). 0.66
B. S. & W: <0.1
Sp. Grav.: 0.975
API: 13.7
Lb./Gal.: 8.1
Viscosity (@ 122°F): 710 cps
Flash: 304°F

CC

Coal (%): 50.09
Oil (%): 39.90
Water (%): 10.01
BTU/Lb.: 15,091 = 138,837 BTU/U.S.G. = 166,731 BTU/I.G.
Sulfur: 0.70
Ash (%): 2.39
Sp. Grav.: 1.09
Lb./Gal.: 9.2 / U.S.G. = 11.0/I.G
Flash: 304°F
Viscosity (@ 122°F): 11,660 cps.
Sp. Ht. 0.335 Btu/lb °F
Percentages are by weight

BROOKFIELD VISCOSITY (COM)

Temp. (f)	Centipoise	Temp. (F)	Centipoise
50	100,000	140	6,760
60	"	150	4,000
70	80,000	160	3,000
80	51,050	170	2,550
90	37,910	180	1,600
100	28,000	190	1,200
110	17,910	200	940
120	12,000	220	710
130	9,590	240	650

Name R. L. Huntington
Position Project Engineer

4,425 U.S. gallons

00092 (CLI Bill of Lading #)
trailer #115

EXHIBIT 5

737 Executive Park, Louisville, Kentucky 40207
(502) 893-0106

COALIQUID. INC.

FUEL ANALYSIS SHEET

SAMPLE # 82022305 DATE 7-16-82

CUSTOMER Iron Ore of Canada

COAL USED (G & G)

Seam: Horse Creek
Source: G & G Coal, London ky
BTU/Lb.: 13,708
Ash (%): 3.97
Sulfur (%): 0.82
Moisture (%): 5.01
Hardness: 47
Fusion(Ash): 2450
Volatiles (%): 35.21
Fixed Carbon (%): 55.75
Percent Passing 200 Mesh: 80.7
325 74.3

COM

Coal (%): 45.45
Oil (%): 47.27
Water (%): 7.28
BTU/Lb.: 15,870 = 142,830 BTU/456. or 171,526 BTU/12.
Sulfur: 0.80
Ash (%): 2.12
Sp. Grav.: 1.08
Lb./Gal.: 9.0 /u.S.G. = 10.81/Lb.
Flash: 292 F
Viscosity (@ 122°F):
Sp. Ht. 0.335 BTU/Lb °F

Percentages are by weight

OIL USED

Type: Fuel Oil 6
Source: Allied O.L. Low, ky
BTU/Lb.: 18,790
Ash (%): 0.89
Sulfur (%). 0.80
B. S. & W:
Sp. Grav.: 0.972
API: 13.9
Lb./Gal.: 8.10
Viscosity (@ 122°F): 318 cps
Flash: 288 F

BROOKFIELD VISCOSITY (COM)

Temp. (f)	Centipoise	Temp. (F)	Centipoise
50	100,000 +	140	6330
60	"	150	5000
70	50,000	160	3650
80	51,500	170	2120
90	35,700	180	1660
100	24,610	190	1230
110	13,500	200	870
120	9200	220	650
130	7210	240	450

Name William R Edwards
Position Quality Control

00100 ? (CLI Bill of Lading #)
trailer # 260

EXHIBIT 5

737 Executive Park, Louisville, Kentucky 40207
(502) 893-0106

COALIQUID. INC.

FUEL ANALYSIS SHEET

SAMPLE # _____ DATE 7-10-82

CUSTOMER Iron Ore of Canada

COAL USED (G & G)

Seam: Horse Creek
Source: G & G Coal, London, Ky
BTU/Lb.: 13,708
Ash (%): 3.93
Sulfur (%): 0.82
Moisture (%): 5.01
Hardness: 47
Fusion(Ash): 2450
Volatiles (%): 35.31
Fixed Carbon (%): 55.75
Percent Passing 200 Mesh:

OIL USED

Type: Fuel Oil 6
Source: Allied Oil (Lou, Ky)
BTU/Lb.: 18,790
Ash (%): 0.89
Sulfur (%). 0.80
B. S. & W:
Sp. Grav.: 0.972
API: 13.9
Lb./Gal.: 8.10
Viscosity (@ 122°F): 318 cps
Flash: 288 F

COM

Coal (%): 50.00
Oil (%): 41.20
Water (%): 8.80
BTU/Lb.: 15091 = 137,328 BTU/USG. & 164,919 BTU/IG.
Sulfur: 0.78
Ash (%): 2.39
Sp. Grav.: 1.09
Lb./Gal.: 9.1/USG. or 10.93/I.G.
Flash: 292 F
Viscosity (@ 122°F):
Sp. Ht. 0.335 BTU/lb °F
Percentages are by weight

BROOKFIELD VISCOSITY (COM)

Temp. (f)	Centipoise	Temp. (F)	Centipoise
50	100,000 +	140	6790
60	"	150	3950
70	81,000	160	2400
80	50,050	170	2290
90	38650	180	1500
100	27500	190	1100
110	17,900	200	920
120	12,600	220	850
130	9900	240	700

Name William L Burrus
Position Quality Control

00097 ? (CLI Bill of Lading #)
Trailer # 260

EXHIBIT 5

737 Executive Park, Louisville, Kentucky 40207
(502) 893-0106

COALIQUID. INC.

FUEL ANALYSIS SHEET

SAMPLE # _____ DATE 7-10-87

CUSTOMER Iron Ore of Canada

COAL USED (G & G)

Seam: Horse Creek
Source: G & G Coal, London, Ky
BTU/Lb.: 13,708
Ash (%): 3.93
Sulfur (%): 0.82
Moisture (%): 5.01
Hardness: 47
Fusion(Ash): 2450
Volatiles (%): 35.31
Fixed Carbon (%): 55.75
Percent Passing 200 Mesh: 92.9

OIL USED

Type: Fuel Oil 6
Source: Allied Oil (Lou, Ky)
BTU/Lb.: 18,790
Ash (%): 0.89
Sulfur (%). 0.80
B. S. & W:
Sp. Grav.: 0.972
API: 13.9
Lb./Gal.: 8.10
Viscosity (@ 122°F): 318 cps
Flash: 288 F

COM

Coal (%): 49.80
Oil (%): 41.00
Water (%): 9.14
BTU/Lb.: 15091 = 137,328 BTU/LG. or 16,919 BTU/LB.
Sulfur: 0.78
Ash (%): 2.89
Sp. Grav.: 1.05
Lb./Gal.: 7.. /U.S.G. ~ 10.93/I.G.
Flash: 292 F
Viscosity (@ 122°F):
Sp. Ht. 0.335 Btu/lb °F
Percentages are by weight

BROOKFIELD VISCOSITY (COM)

Temp. (f)	Centipoise	Temp. (F)	Centipoise
50	100,000 +	140	6780
60	"	150	3757
70	81,000	160	2900
80	50,050	170	2290
90	38650	180	1500
100	27500	190	1100
110	17900	200	970
120	12,600	220	850
130	9900	240	700

Name William L Brown
Position Quality Control

00099 ? (CLI Bill of Lading #)
trailer # 260

EXHIBIT 5

737 Executive Park, Louisville, Kentucky 40207
(502) 893-0106

COALIQUID. INC.

FUEL ANALYSIS SHEET

SAMPLE # 82022405 DATE JUL 17 1982

CUSTOMER Canada (Iron Ore)

COAL USED (~~Petro Coke~~)

Seam: Horse Creek
Source: G&G London, Ky
BTU/Lb.: 13,307
Ash (%): 3.93
Sulfur (%): 0.82
Moisture (%): 5.01
Hardness: 47
Fusion(Ash): 2450 F
Volatiles (%): 35.31
Fixed Carbon (%): 55.75
Percent Passing 200 Mesh: 82.9
325 69.6

OIL USED

Type: Fuel Oil 6
Source: Allied Oil
BTU/Lb.: 18,790
Ash (%): 0.69
Sulfur (%): 0.80
B. S. & W: <0.1
Sp. Grav.: 0.972
API: 13.9
Lb./Gal.: 8.1
Viscosity (@ 122°F): 318 cps
Flash: 288F

COM

Coal (%): 48.96
Oil (%): 41.92
Water (%): 9.12
BTU/Lb.: 15,091 = 138,083 BTU/USG or 165,825 BTU/I.G.
Sulfur: 0.78
Ash (%): 2.67
Sp. Grav.: 1.08
Lb./Gal.: 9.15 /U.S.G. or 10.988/I.G.
Flash: 292 F
Viscosity (@ 122°F): 10,000
Sp. Ht. 0.335 Btu/lb °F
Percentages are by weight

BROOKFIELD VISCOSITY (COM)

Temp. (f)	Centipoise	Temp. (F)	Centipoise
50	100,000	140	6200
60	11	150	4950
70	86,600	160	3310
80	60,500	170	2880
90	44700	180	2100
100	30,000	190	1880
110	17250	200	1440
120	10,000	220	1100
130	7900	240	950

Name William L Brown
Position Quality Control

~~HHV~~ 5340 USG 00101 (CLI Bill of Lading #)
Trailer # 312.

737 Executive Park, Louisville, Kentucky 40207
(502) 893-0106

EXHIBIT 5

COALIQUID. INC.

FUEL ANALYSIS SHEET

SAMPLE # 82021905 DATE JUL - 6 1982

CUSTOMER Iron Ore Canada

COAL USED (G&G)

Seam: Horse Creek
Source: G&G Coal, London Ky
BTU/Lb.: 13,951
Ash (%): 3,80
Sulfur (%): 0.78
Moisture (%): 3,99
Hardness: 47
Fusion(Ash): 2450 (Fluid)
Volatiles (%): 40.17
Fixed Carbon (%): 52.09
Percent Passing 200 Mesh: 92.9

OIL USED

Type: Fuel Oil 6
Source: Allied Oil
BTU/Lb.: 18,790
Ash (%): 0,28
Sulfur (%). 0,66
B. S. & W: <0,1
Sp. Grav.: 0.975
API: 13,7
Lb./Gal.: 8,1
Viscosity (@ 122°F): 710 cps
Flash: 304 F

COM

Coal (%): 50,32
Oil (%): 41,66
Water (%): 8,02
BTU/Lb.: 15,091 = 138,837 BTU/U.S.G. ≈ 166,731 BTU/I.G.
Sulfur: 0,70
Ash (%): 2,39
Sp. Grav.: 1,09
Lb./Gal.: 9.2 U.S.G. ≈ 11.0/IG.
Flash: 304 F
Viscosity (@ 122°F): 11,660 cps
Sp. Ht. 0.335 BTU/Lb °F
Percentages are by weight

BROOKFIELD VISCOSITY (COM)

Temp. (f)	Centipoise	Temp. (F)	Centipoise
50	100,000+	140	6760
60	11	150	4000
70	80,000	160	3000
80	51,050	170	2560
90	37,910	180	1600
100	28,000	190	1200
110	17,910	200	940
120	12,000	220	710
130	9590	240	650

Name William L Brown
Position Quality Control Mgr.

5,213 U.S. gallons NET

00091 (CLI Bill of Lading #)
trailer # 115

EXHIBIT 5A

FUEL H_2 and C CONTENT

No.6 OIL:

0.85C
0.11 H_2
- Water

COAL:

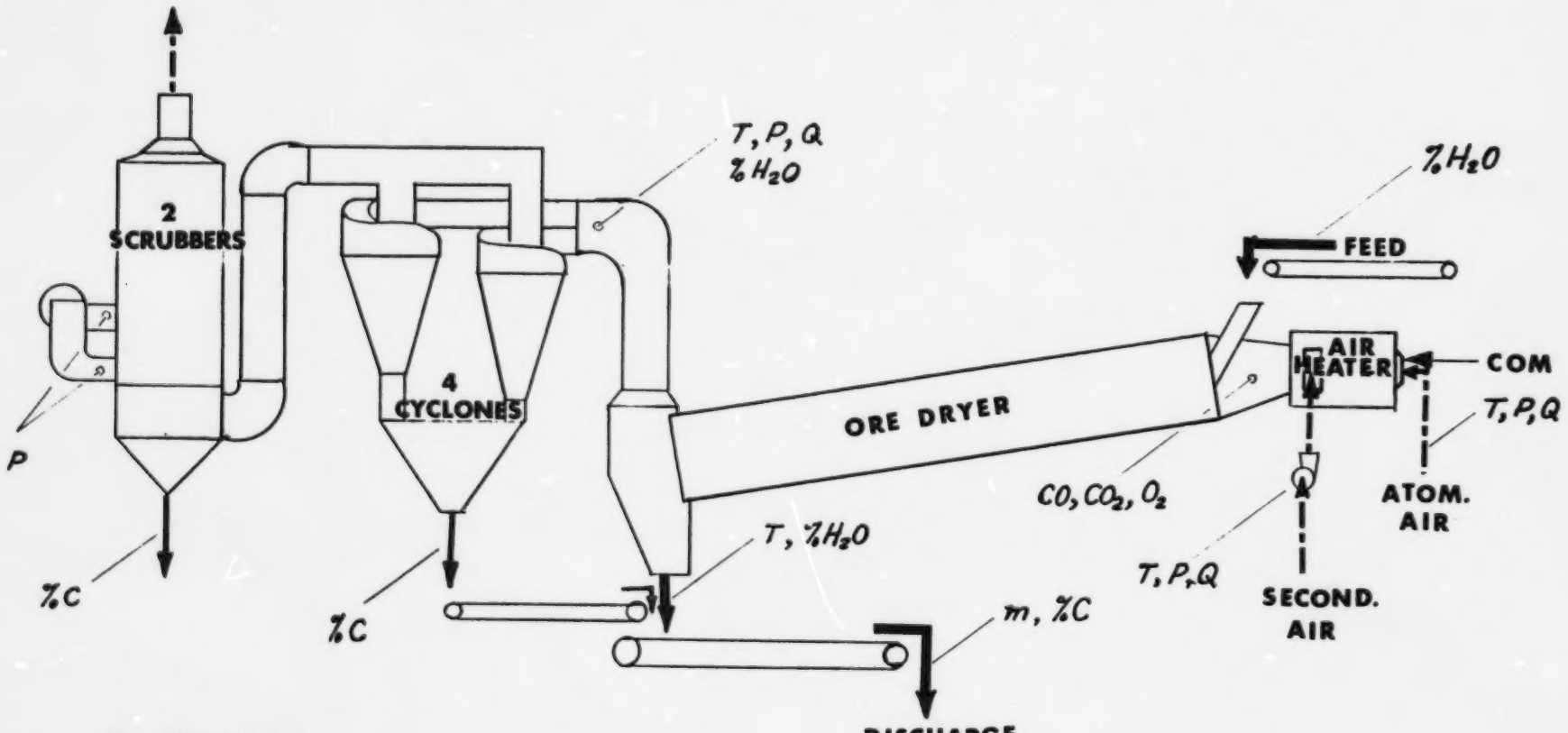
Class II Bituminous
Group: 3 High volatile A
Dry fixed carbon less than 69%
Dry volatile matter more than 31%

0.852C
0.054 H_2
0.07 O_2
0.016 N_2

COM: $C = (0.5 \times 0.852 + 0.4 \times 0.85) = 0.766$ lb/lb fuel

$H_2 = (0.5 \times 0.054 + 0.4 \times 0.11) = 0.071$ lb/lb fuel

DRYER SAMPLING ARRANGEMENT



P = PRESSURE
T = TEMPERATURE
Q = FLOW
m = MASS

EXHIBIT 6

EXHIBIT 7

COM COMBUSTION TEST

DRYER FEED AND DISCHARGE MOISTURE

Date	Time	% Moisture Feed	% Moisture Discharge
82 07 20	09:00	15.0	
	10:00	14.2	
	11:00	15.8	
	12:00	13.6	
	13:00	15.0	
	14:00	14.0	10.5
	15:00	13.9	
	16:00	13.9	
	17:00	14.1	
	18:00	14.3	10.5
	19:00	14.8	
	20:00	13.2	
	21:00		
	22:00		9.2
82 07 21	00:00-08:00	15.1	
	09:00	15.8	
	10:00	14.3	
	11:00	13.4	
	12:00	14.2	
	13:00	13.3	
	14:00	14.2	
	15:00	15.7	
	16:00	14.7	
	17:00	15.9	
	18:00	14.0	
	19:00	14.1	
	20:00	14.3	
	21:00	15.8	
	22:00	15.5	10.1
82 07 22	00:00 08:00	14.6	9.4
	09:00	14.4	
	10:00	14.5	9.3
	11:00	15.0	
	12:00		
	13:00	14.6	
	14:00	14.1	10.0
	15:00	14.0	
	16:00	14.7	
	17:00	15.2	
	18:00	16.2	8.9
	19:00	16.6	
	20:00	16.2	
	21:00	14.6	
	22:00	16.5	8.7
	23:00	17.0	
	24:00	16.8	
82 07 23	01:00	15.8	
	02:00	15.3	
	03:00	16.0	
	04:00	15.2	8.6
	05:00	15.5	
	06:00	15.2	
	07:00	14.0	
	08:00	-	
	09:00	16.0	
	10:00	15.6	
	11:00	14.1	8.5
	12:00	14.8	
	13:00	15.3	
	14:00	15.6	
	15:00	15.0	
	16:00	12.0	
	17:00	12.9	8.9
	18:00	13.8	
	19:00	13.5	
	20:00	14.9	7.2
	21:00	14.1	
	22:00	14.6	

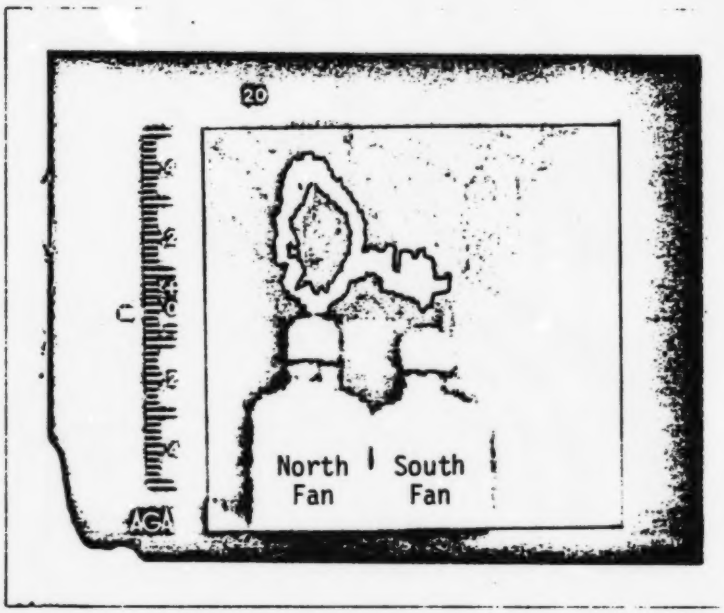
EXHIBIT 8

CARBON CONTENT IN DRYER DISCHARGE

DATE	% C	TEST
82 06 15	0.05	Bunker «C»
16	0.05	"
17	0.04	"
18	0.03	"
19	0.04	"
82 07 20	0.07	COM
21	0.04	"
22	0.05	"
23	0.03	"
24	0.04	"

EXHIBIT 9

THERMOGRAPH OF SCRUBBER EXHAUST



ISOTHERMS SHOW AREAS OF EQUAL TEMPERATURE, THEREFORE, CENTER OF LEFT PLUME WILL BE HOTTER THAN CENTER OF RIGHT PLUME.

EXHIBIT 9A*

LIME KILN SCRUBBER EMISSIONS

Using Coen Burner with No.6 Oil

Date	Scrubber Differential	Particulate Out Lbs/hr.
79 07 04	22.5	6.4
79 07 06	21.5	5.0
Average	22.0	5.7

Using Forney Burner with Coaliquid

79 11 18	20.5	4.6
79 11 19	20.5	5.3
79 11 21	20.0	5.0
79 11 23	20.5	4.9
79 11 26	20.5	4.8
79 11 27	20.5	4.6
Average	20.4	4.9

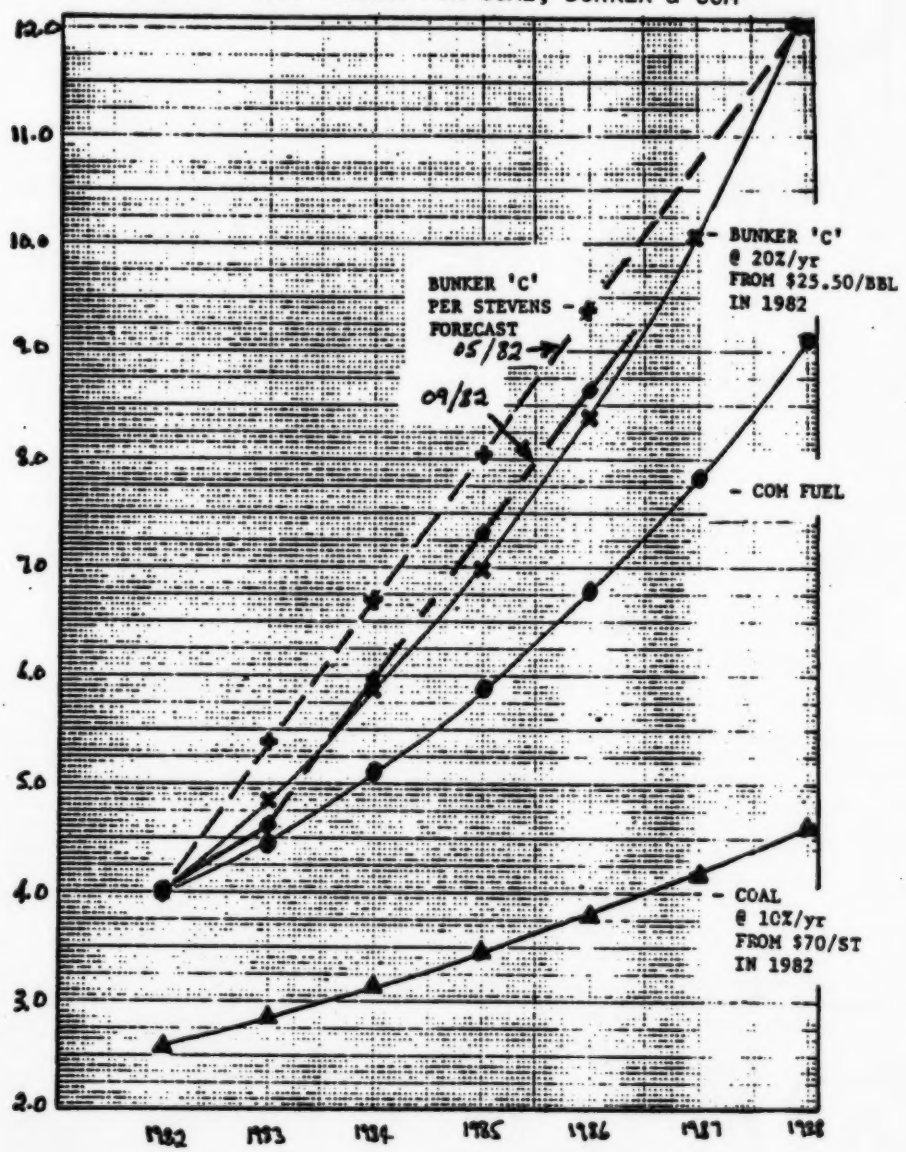
Using Forney Burner with No.6 Oil

79 11 28	20.5	4.7
79 11 29	20.5	5.8
Average	20.5	5.3

*Reproduced from: Hawkins, G.T. «Industrial Utilization of Coal-Oil mixtures» Energy Technology IX. Washington, 1982

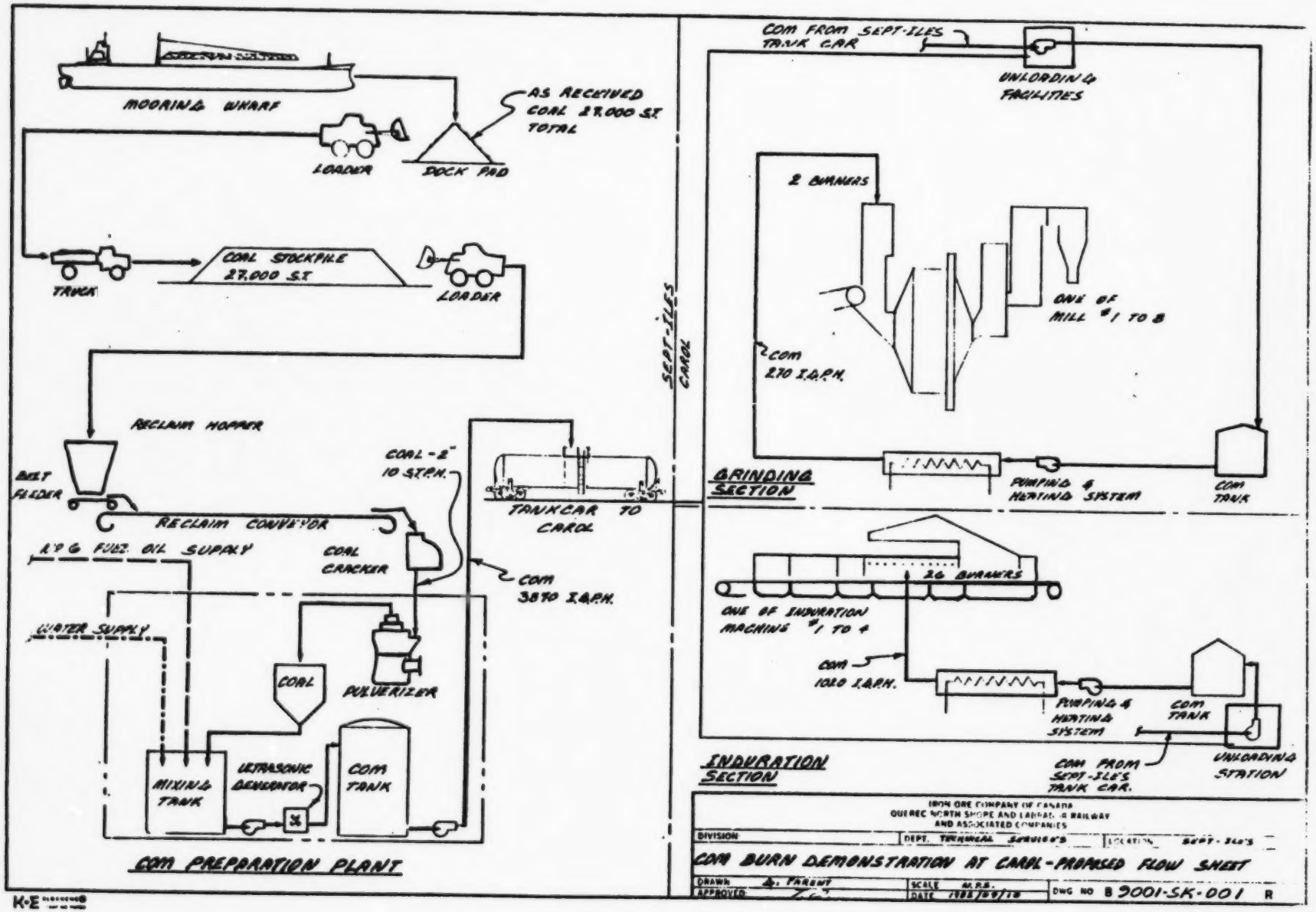
EXHIBIT 10

EXPECTED PRICE TRENDS FOR COAL, BUNKER & COM*



* COM fuel price includes 16.80$/ST Preparation cost

PROPOSED FLOWSHEET - COM BURN DEMONSTRATION AT CAROL



IRON ORE COMPANY OF CANADA
QUEBEC NORTH SHORE AND LABRADOR RAILWAY
AND ASSOCIATED COMPANIES

DIVISION	DEPT. TECHNICAL SERVICES	LOCATION SEPT-ILES	
COM BURN DEMONSTRATION AT CAROL - PROPOSED FLOW SHEET			
DRAWN A. PARENT	SCALE N.T.S.	DWG NO B 9001-SK-001	R
APPROVED	DATE 1981/09/18		

K-E

EXHIBIT 11

EXHIBIT 11A

ANALYSE DES FRAIS - COST ANALYSIS

ENTREPRISE / PROJECT: COM BURN DEMONSTRATION AT CAROL PROJECT

NO DE FEUILLE / SHEET No.: SUMMARY

EMPLACEMENT / LOCATION: "ORDER-OF-MAGNITUDE"

NO DE DEVIS / ESTIMATE NO: NFE-1982-26

DATE: 1982-09-09

ARCHITECT(E)

OWNER

QUANTITES / QUANTITIES BY: HN/DH

PRIX / PRICES BY: HN/DH

EXTENSIONS / EXTENSIONS BY: HN/DH

VERIFIE / CHECKED BY

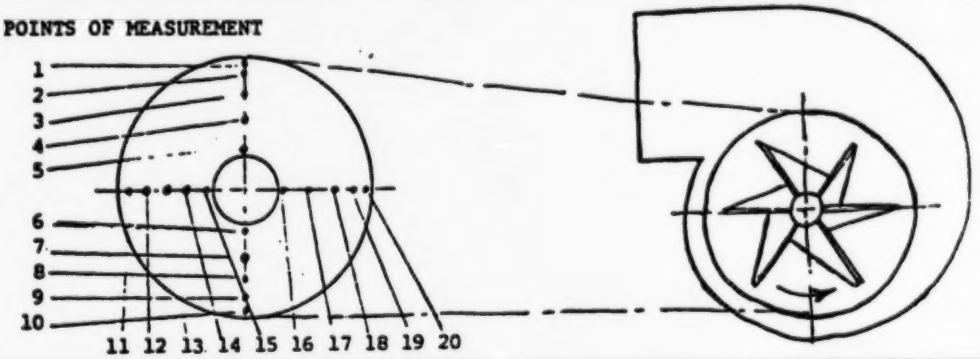
DESCRIPTION	QUANTITE / QUANTITY	UNITE / UNIT	MATERIEL / MATERIAL UNIT(E)	MATERIEL / MATERIAL TOTAL	MAIN D'OEUVRE / LABOUR UNIT(E)	MAIN D'OEUVRE / LABOUR TOTAL	TOTAL DES FRAIS / TOTAL COST UNIT(E)	TOTAL DES FRAIS / TOTAL COST TOTAL
1.0 SEPT-ILES PORTION								2,760,000
COAL LIQUID PACKAGE								1,022,000
I.O.C. PORTION								
2.0 CR INDURATION								493,000
3.0 CR GRINDING								209,000
SUB-TOTAL:								4,484,000
ENGINEERING (8% ON IOC PORTION - 1,724 M)								138,000
CONSTRUCTION & PROJECT MANAGEMENT	(BY I.O.C.)							NIL
TAXES (WHERE APPLICABLE)								INCL.
FREIGHT (3% on 1,724 M)								50,000
SUB-TOTAL:								4,672,000
CONTINGENCY 20%								934,000
TOTAL:								5,606,000
							SAY	5,600,000

NOTE: Above is in Canadian funds, 1982 dollars and the estimate has an accuracy of ± 30%

ZV ORE DRYER TEST COM BURN TEST NO.: 1 13:30 DATE: 82 07 20

ATOMIZING AIR BLOWER BY: B. MARSHALL & DURET

POINTS OF MEASUREMENT



ANEMOMETER READINGS

POINT	IN	FT/MIN
1	$\frac{1}{8}$	—
2	1	750
3	$1\frac{7}{8}$	—
4	$2\frac{7}{8}$	—
5	$4\frac{1}{2}$	400
6	$8\frac{1}{2}$	850
7	$9\frac{3}{8}$	750
8	$10\frac{5}{8}$	—
9	$11\frac{1}{2}$	620
10	$12\frac{1}{2}$	—
11	$\frac{1}{8}$	—
12	1	750
13	$1\frac{7}{8}$	—
14	$2\frac{7}{8}$	—
15	$4\frac{1}{2}$	800
16	$8\frac{1}{2}$	850
17	$9\frac{3}{8}$	860
18	$10\frac{5}{8}$	—
19	$11\frac{1}{2}$	530
20	$12\frac{1}{2}$	—
TOTAL		7,660
AVERAGE vel. V		766

A Cross-sectional area = 3.41 [FT^2]

V Average linear velocity = 766 [FT/MIN]

Q Quantity of air flowing = AV [CFM]

Q = 2612 CFM

T_i Inlet air temperature = 75 °F

Wet bulb temperature = F

$$Q_s = Q \frac{460 + 70}{460 + T_i}$$

Q_s = 2588 SCFM

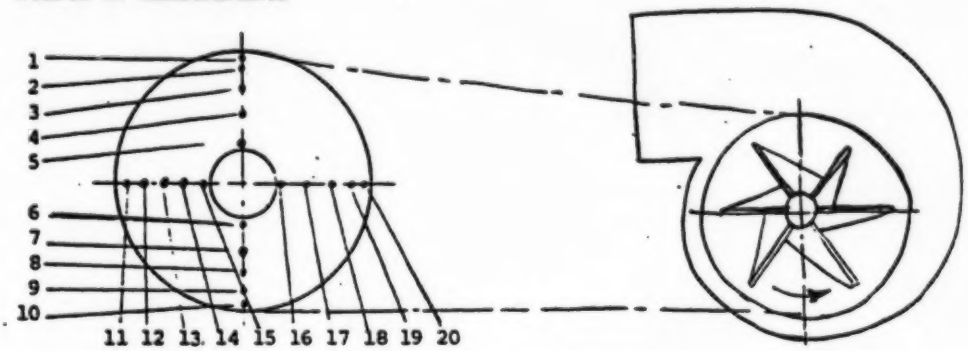
NOTES: Standard conditions T = 70 °F

p = 14,696 psia

2V ORE DRYER TEST: COM BURN TEST NO.: 1 DATE: 82 07 20

FORCED DRAFT FAN 13:30 BY: S BURGESS V. DURET

POINTS OF MEASUREMENTS



ANEMOMETER READINGS

POINT	IN	FT/MIN
1	1½	2450
2	4½	2550
3	7½	2550
4	11½	2800
5	17½	2950
6	32⅞	3000
7	38½	2500
8	42½	2150
9	45⅞	2050
10	48½	1700
11	1½	1550
12	4½	2250
13	7½	2600
14	11½	2700
15	17½	2950
16	32⅞	3000
17	38½	2500
18	42½	2150
19	45⅞	2050
20	48½	1700
TOTAL		48150
AVERAGE vel.V		2407.5

A Cross-sectional area = 12.85 [FT²]

V Average linear velocity = 2407.5 [FT/MIN]

Q Quantity of air flowing = AV [CFM]

Q = 30,936 CFM

T_i Inlet air temperature = 78 F

Wet bulb temperature = F

$$Q_s = Q \frac{460 + 70}{460 + Ti}$$

Q_s = 30,476 SCFM

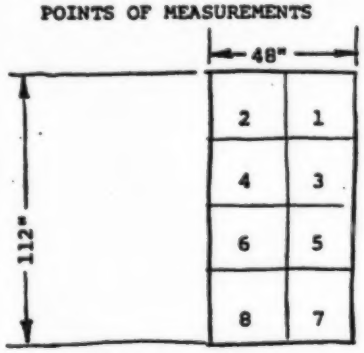
NOTES: Standard conditions T = 70 °F

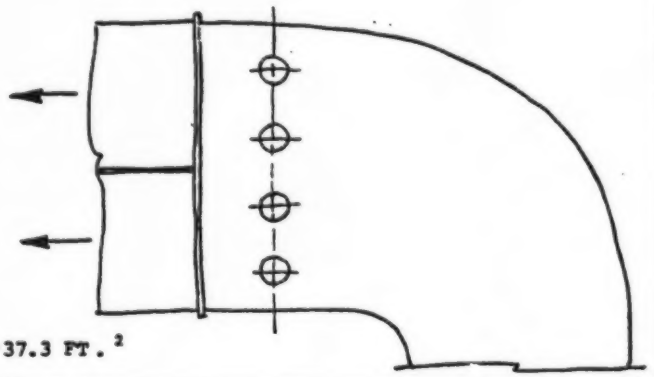
p = 14,696 psia

ZV ORE DRYER TEST: COM BURN TEST NO: 1 DATE: 82 07 20

CYCLONES INLET DUCT 13:30 BY: B. MARSHALL F. ELLIS

POINTS OF MEASUREMENTS





Cross sectional area A = 37.3 FT.^{2}

Pitot traverse readings (962-8247) B: kPa x 6.894757

POINTS	VP	$\sqrt{VP}$
1	0.56	0.748
2	0.42	.648
3	0.40	.632
4	0.42	.648
5	0.27	.519
6	0.73	.854
7	1.05	1.025
8	1.10	1.049
TOTAL		6.423
AVERAGE	$\sqrt{VP}$	0.803

Wet bulb temp. = 116.6 °F

Atmospheric pressure B = 29.84 in Hg

Static pressure: -1.9 in Water

x 0.0735 = S: -0.14 in Hg

Air temperature: 174 °F

+460 = T: 634 °R

$V = 174\ (f)\ \sqrt{VP}\ \sqrt{\frac{29.92 \times T}{P}}$

$V = 174\ (0.74)\ (0.803)\ \sqrt{\frac{29.92 \times (634)}{(29.74)}}$

V = 2,613 FT/MIN

Air flow Q = AV

Q = 97,466 FT^3/MIN

NOTES: Correction factor for "S type" pitot tube f = 0.74

P = B + S in Hg

EXHIBIT 13(A)

SPECIFICATIONS

SHORT TERM BURN TEST AT CR

Indurating machine #6 may be considered as divided into three functional sections, namely, updraft drying; then the downdraft drying section which includes: downdraft drying, preheating, firing and after firing; and then the updraft cooling section. Forty-six wind boxes are provided. Wind box and burner distribution is as follows:

	Wind box		Burners	Million Btu/hr
Updraft				
Updraft drying	7	(1 - 7)	-	-
Downdraft				
Downdraft drying	3 1/2	(8 - 11)	-	-
Preheating	2 1/2	(11 - 13)	4	12
Firing	12	(14 - 25)	24	12
After firing	5	(26 - 30)	6	6
Updraft				
First stage cooling	13	(31 - 43)	-	
Second stage cooling	3	(44 - 46)	-	
TOTAL	46		34	432

The combustion equipment in the downdraft section includes thirty-four (Bunker «C») burners with propane gas igniters giving a burner distribution of four in the preheating section, twenty-four in the firing section (1st zone, 2nd zone and 3rd zone) and six in the after-firing section.

To be converted (1st zone of firing section)	8 burners
Rated capacity (ea.)	12×10^6 Btu/hr
Estimated fuel consumption (Bunker «C») per burner	66 IG/hr
Test duration: $(1 \text{ month} \times \frac{30 \text{ days}}{\text{month}} \times \frac{24 \text{ hrs}}{\text{day}}$	720 hours
Bunker «C» consumption by 8 burners in 1 month	380 200 IG
Equivalent «COM» required $\frac{380\ 200 \times 180\ 000}{166\ 000}$	412 200 IG
Estimated «COM» consumption: 8 burners	13 740 IG/day
: 8 burners	572 IG/hr
: 1 burner	71.5 IG/hr

EXHIBIT 13(B)

SUMMARY OF COST ESTIMATE

SHORT TERM BURN TEST AT CAROL

1.	COM Fuel & Transportation			
	a)	Cost of fuel (412 000 IG)	$ 302,107	
	b)	Transportation: Shelbyville-Champlain	107,040	
		Champlain-Sept-Iles	288,400	
	c)	Freight charge Sept-Iles to Labrador City	25,750	
	d)	COM transferring and heating	9,696	
	e)	Heating of tank cars	30,000	
			$ 829,993	$ 829,993
2.	COM Handling			
	a)	Unloading	$ 17,000	
	b)	COM line	23,750	
	c)	Storage tank	45,000	
	d)	Pumping and heating	40,000	
	e)	Supply and return line	21,200	
	f)	Electrical	10,000	
			$ 156,950	156,950
3.	Burner Modifications			
	a)	New tips	$ 6,800	
	b)	Fuel train	10,000	
	c)	COM heating	12,000	
			$ 28,800	28,800
	Sub-total			$1,015,743
	Engineering on items 2 and 3 (8%)			81,259
	TOTAL cost of Short Burn Test			$1,097,002
	SAY			$1,100,000

8.0 PHOTOGRAPHS

Drying Plant

Fuel Storage Tanks

COM Handling Units

COM Handling Unit

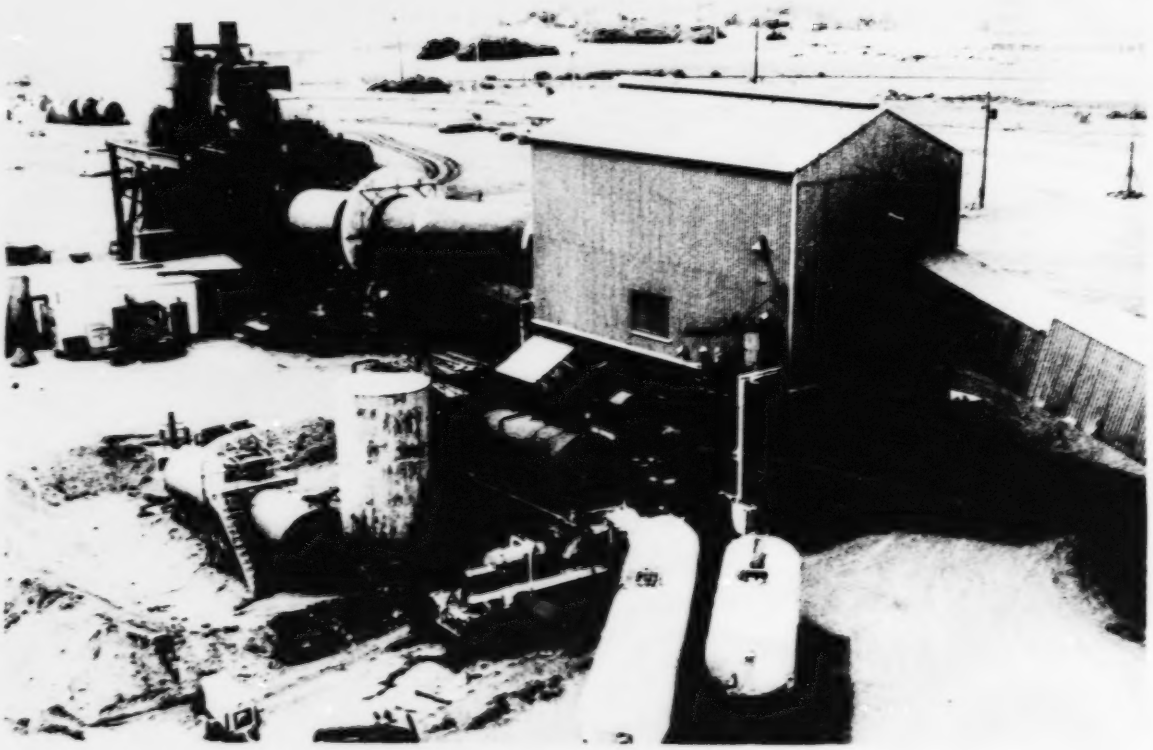
Burner and Atomizing Air Fan

COM Burner

Drying Plant

COM COMBUSTION TEST

DRYING PLANT



General view of the ore dryer showing air heater building (right), rotary kiln (center) and exhaust gases handling equipment (left). Two COM tankers and the slurry handling unit are seen in the foreground.

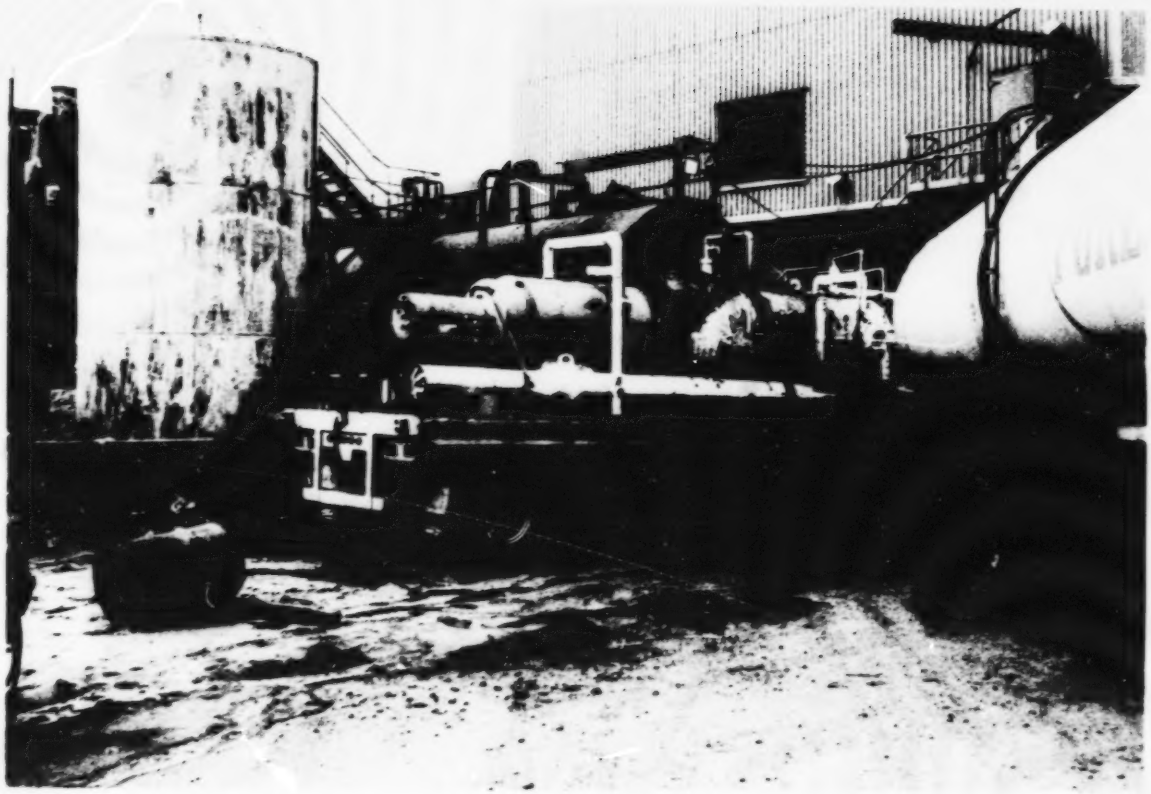
COM COMBUSTION TEST

FUEL STORAGE TANKS

This picture shows the different storage tanks. From left to right: COM trailers (2), day tank, diesel fuel (vertical tank) and Bunker «C» storage.

COM COMBUSTION TEST

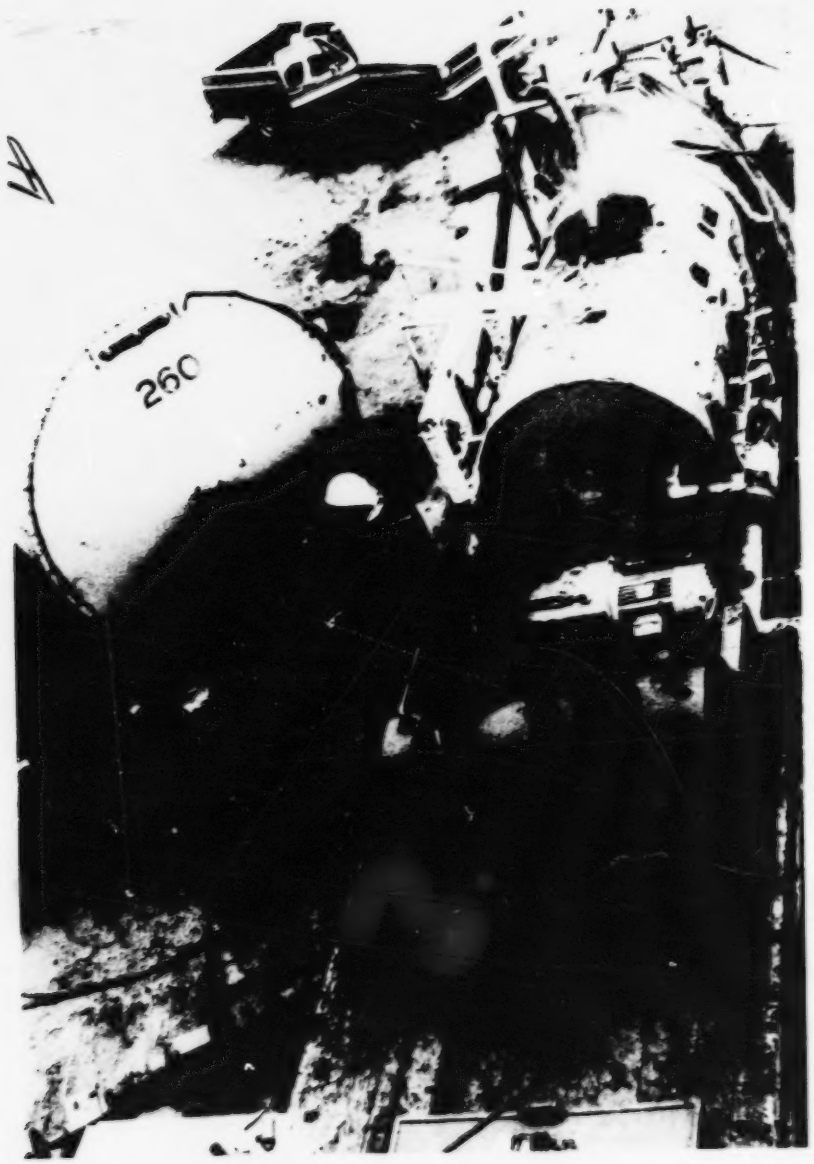
COM HANDLING UNIT



COM handling trailer (center) shows the steam generator, the COM day tank and one of two COM heat exchangers.

COM COMBUSTION TEST

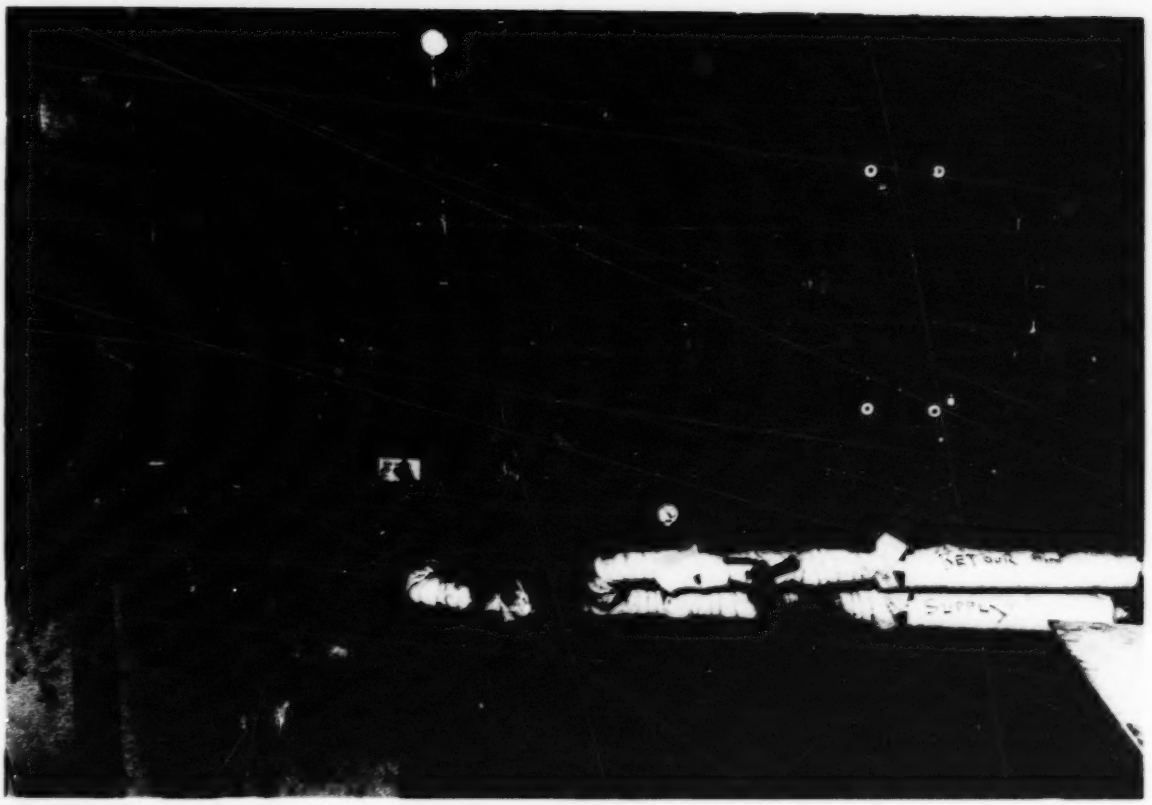
COM HANDLING UNIT



COM handling unit included steam generator (far end), day tank and COM heaters (on each side of day tank). Supply and return lines can be seen at the right. COM is being unloaded from tanker No.260, through Moyno pump (bottom left).

COM COMBUSTION TEST

BURNER AND ATOMIZING AIR FAN



Forney-Verloop Burner (top left) and atomizing air fan (foreground left). COM supply and return lines are shown in the center of the picture.

COM COMBUSTION TEST

COM BURNER

Dryer attendant is seen operating swirl air control handle.

COM COMBUSTION TEST

DRYING PLANT

General view of the drying plant showing dried ore cars in the foreground.